




OPERATING AND SERVICE MANUAL

( PART NO. 400D/H/L-902)

MODEL 400D

SERIALS PREFIXED: 310-

MODEL 400H

SERIALS PREFIXED: 313-

MODEL 400L

SERIALS PREFIXED: 313-

AND

SPECIF. H02-400D

SERIALS PREFIXED: 310-

VACUUM TUBE VOLTMETER

Appendix B, Manual Backdating
Changes adapts this manual to:

Models 400D/H02-400D,	Serial Nos. 310-45570 and below
Models 400H/L,	Serial Nos. 313-22176 and below
Model 400H,	Serial Nos. 017-12026 and below
Model 400L,	Serial Nos. 048-13256 and below
Models 400DR/HR/LR,	All Serial Nos.

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TABLE OF CONTENTS

Section	Page	Section	Page
I GENERAL DESCRIPTION	1-1	5-22 Testing Voltmeter Performance . .	5-5
1-1 Introduction	1-1	5-24 Calibration and Frequency Response Adjustments	5-8
1-4 Description	1-1	VI ILLUSTRATED PARTS	
1-11 Accessories	1-2	BREAKDOWN	6-1
II INSTALLATION	2-1	6-1 General	6-1
2-1 Unpacking and Inspection	2-1	VII GROUP ASSEMBLY PARTS	
2-3 Line Voltage Requirement	2-1	BREAKDOWN	7-1
2-5 Power Line Connections	2-1	7-1 Vacuum Tube Voltmeter	
2-8 Installation	2-1	400D/H/L	7-1
2-10 Operation Check	2-1	7-2 Main Chassis Assembly	7-3
III OPERATING INSTRUCTIONS	3-1	7-3 Range Switch Assembly	
3-1 Instrument Turn-On	3-1	400D-19A	7-8
3-3 General Operating Information	3-1	7-4 Printed Circuit Board	
3-12 Low-Level Measurements and Ground Currents	3-2	Assembly 400D-75G	7-9
3-14 Measurement of Voltage	3-2	7-5 Printed Circuit Board	
3-17 Measurement of Decibels	3-3	Assembly 400D-75F	7-11
3-20 Impedance Correction Graph	3-3	7-6 Printed Circuit Board	
3-22 Use of Voltmeter Amplifier	3-4	Assembly 400D-65C	7-12
IV CIRCUIT DESCRIPTION	4-1	VIII NUMERICAL INDEXES	8-1
4-1 Block Diagram	4-1	Part No. Numerical Index	8-1
4-3 Input Voltage Divider and Step Attenuator	4-1	Hewlett-Packard Stock No. Index	8-2
4-7 Broadband Voltmeter Amplifier	4-1	IX REFERENCE DESIGNATION	
4-10 Indicating Meter Circuit	4-1	INDEX	9-1
4-14 Power Supply	4-2		
V MAINTENANCE	5-1	Appendix	
5-1 Scope	5-1	A CODE LIST OF MANUFACTURERS	
5-3 Precautions	5-1	Appendix	
5-5 Test Equipment Required	5-1	B SALES AND SERVICE OFFICES	
5-7 Meter Zero Adjustment	5-1	Appendix	
5-9 Cabinet Removal	5-2	C MANUAL BACKDATING CHANGES	
5-10 Tube Replacement	5-2		
5-13 Replacement of Special Parts	5-2		
5-17 Trouble Shooting	5-3		
5-20 Testing the Power Supply	5-3		

LIST OF ILLUSTRATIONS

Number	Title	Page	Number	Title	Page
1-1.	Vacuum Tube Voltmeters Models 400D, 400H, and 400L	1-0	5-6.	Test Setup for Calibration Check and Adjustments	5-7
1-2.	Table of Specifications	1-1	5-7.	Test Setup for Frequency Response Check and Adjustment	5-8
3-1.	Voltmeter Front Panel, Showing Controls and Connectors	3-0	5-8.	Voltage and Resistance Diagram	5-10
3-2.	Effect of Harmonics on Voltage Measurements	3-1	5-9.	Diagram of RANGE Switch	5-11
3-3.	Test Setup for Avoiding Ground Loop	3-2	5-10.	Voltmeter Schematic Diagram	5-13
3-4.	Impedance Correction Graph	3-5	7-1.	400D/H/L Vacuum Tube Voltmeter . .	7-1
4-1.	Voltmeter Block Diagram	4-0	7-2.	Main Chassis Assembly (Sheet 1 of 2)	7-3
4-2.	Simplified Schematic of Meter Bridge Circuit	4-2	7-2.	Main Chassis Assembly (Sheet 2 of 2)	7-5
5-1.	Test Equipment Required	5-1	7-3.	RANGE Switch Assembly	7-8
5-2.	Adjustments Required When Tubes Are Replaced	5-2	7-4.	Printed Circuit Board Assembly Part No. 400D-75G	7-9
5-3.	Left Side View of Voltmeter Chassis . .	5-4	7-5.	Printed Circuit Board Assembly Part No. 400D-75F	7-10
5-4.	Right Side View of Voltmeter Chassis .	5-5	7-6.	Printed Circuit Board Assembly Part No. 400D-65C	7-12
5-5.	Trouble-Shooting Procedure	5-6			

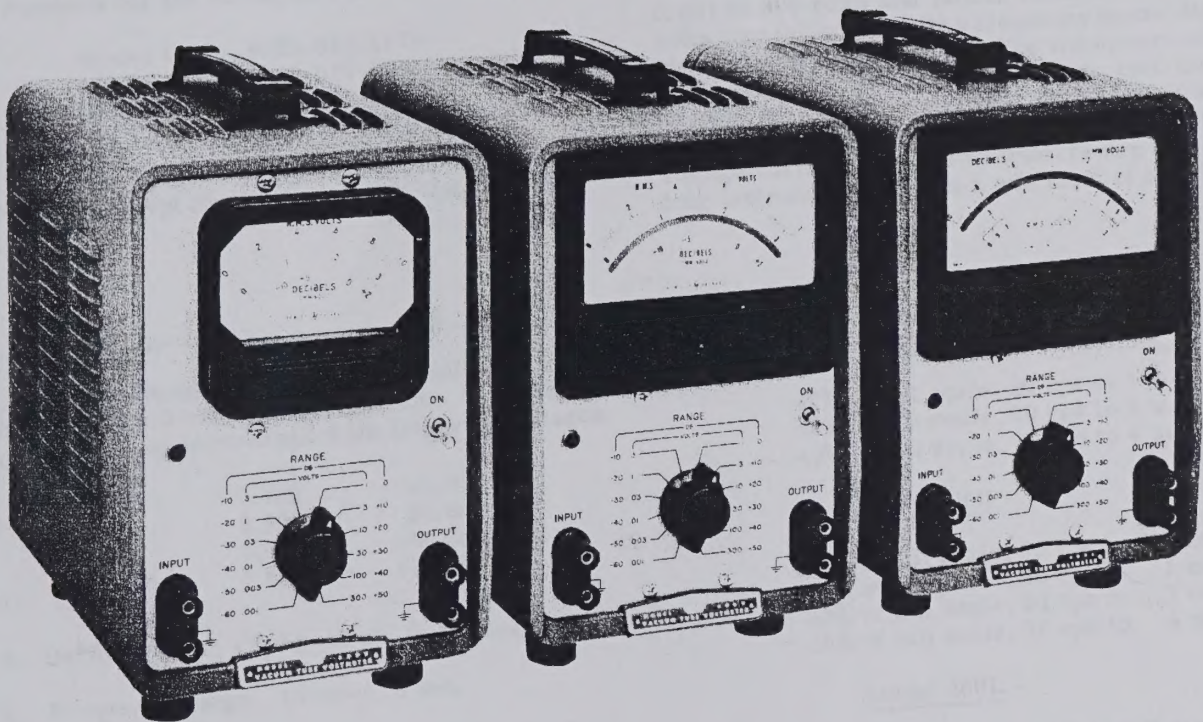


Figure 1-1. Vacuum Tube Voltmeters Models 400D, 400H, 400L

SECTION I

GENERAL DESCRIPTION

1-1. INTRODUCTION. (See figure 1-1.)

1-2. This manual contains operating and servicing instructions, and a parts breakdown, for the Models 400D, 400H, and 400L Vacuum Tube Voltmeters manufactured by the Hewlett-Packard Company. The Model 400D Voltmeter is similar to a military counterpart, Electronic Voltmeter ME-30A/U, in appearance and operation, but contains modified electrical circuits to obtain improved performance. Applicable Federal Stock Numbers for the voltmeters are as follows:

Model 400D: 6625-643-1670
Model 400H: 6625-557-8261
Model 400L: 6625-729-8360

1-3. The Models 400D, 400H, and 400L Voltmeters are the same except for the differences listed in Figure 1-2.

a. The front panel meters are different in each model, as described in paragraph 1-6.

b. The accuracy specifications are different for each model, as described in figure 1-2.

1-4. DESCRIPTION.

1-5. The Hewlett-Packard Models 400D, 400H, and 400L Vacuum Tube Voltmeters are general purpose, portable electronic a-c voltmeters of high sensitivity and stability. They are suited to both laboratory and field use. Models 400D/H measure a-c voltages from 0.001 to 300 volts and Model 400L from .003 to 300 volts rms full scale, with a frequency bandwidth covering 10 cps to 4 megacycles. The voltmeters are compact, accurate, and rugged and have fast meter response, high input impedance, stable calibration accuracy, and freedom from the effects of normal line voltage variations. The voltmeters are designed for long instrument life with a minimum of servicing.

a. Voltage Range: 400D/H - 0.1 millivolt to 300 volts; 400L - 0.3 millivolt to 300 volts, in 12 ranges providing full-scale readings of the following voltages:

0.001	0.100	10.00
0.003	0.300	30.00
0.010	1.000	100.00
0.030	3.000	300.00

b. Decibel Range: -72 to +52 db, in 12 ranges.

c. Frequency Range: 10 cps to 4 mc.

d. Input Impedance: 10 megohms shunted by 15 pf (15 μ f) on ranges 1.0 volt to 300 volts; 25 pf on ranges 0.001 volt to 0.3 volt.

e. Stability: Line voltage variations of $\pm 10\%$ do not reduce the specified accuracy, and line voltage transients are not reflected in the meter reading. Electron tube deterioration to 75% of normal transconductance affects accuracy less than 0.5% from 20 cps to 1 mc.

f. Amplifier: OUTPUT terminals are provided so that the voltmeter can be used to amplify small signals or to enable monitoring of waveforms under test with an oscilloscope. Output voltage is approximately 0.15 volt rms on all ranges with full-scale meter deflection. Amplifier frequency response is same as the voltmeter. Internal impedance is approximately 50 ohms over entire frequency range.

g. Accuracy: Model 400D -

$\pm 2\%$ of full scale, 20 cps to 1 mc;
 $\pm 3\%$ of full scale, 20 cps to 2 mc;
 $\pm 5\%$ of full scale, 10 cps to 4 mc.

Model 400H -

$\pm 1\%$ of full scale, 50 cps to 500 kc;
 $\pm 2\%$ of full scale, 20 cps to 1 mc;
 $\pm 3\%$ of full scale, 20 cps to 2 mc;
 $\pm 5\%$ of full scale, 10 cps to 4 mc.

Model 400L -

$\pm 2\%$ of reading or $\pm 1\%$ of full scale, whichever is more accurate, 50 cps to 500 kc.
 $\pm 3\%$ of reading or $\pm 2\%$ of full scale, whichever is more accurate, 20 cps to 1 mc.
 $\pm 4\%$ of reading or $\pm 3\%$ of full scale, whichever is more accurate, 20 cps to 2 mc.
 $\pm 5\%$ of reading 10 cps to 4 mc.

h. Power Requirement: 115/230 volts $\pm 10\%$, 50 to 1000 cps, approximately 100 watts.

i. Size: 11-3/4 in. high, 7-1/2 in. wide, 12 in. deep.

j. Weight: 18 lbs; shipping weight approximately 23 lbs.

Figure 1-2. Table of Specifications

1-6. Each model voltmeter has three calibrated scales on the panel meter. The Models 400D and 400H have two linear VOLTS scales, 0 to 1 and 0 to 3, and one DECIBELS scale, -12 to +2 db. The meters used in the Models 400H and 400L are larger and include a mirror to eliminate parallax in viewing and to facilitate use of the higher scale calibration accuracy of these models. The Model 400L VOLTS scales are logarithmic in calibration, from 0.3 to 1 and 0.8 to 3; and the DECIBELS scale is linear. In all models, the VOLTS scales are calibrated to indicate the root-mean-square (rms) value of an applied sine wave. Actual meter deflection is proportional to the average value of the applied signal, thereby minimizing additional meter deflection due to noise and harmonic distortion.

1-7. A voltmeter output signal is provided at the front panel OUTPUT terminals. This output is proportional to the meter reading and has a waveshape similar to the applied signal. This signal level is about 0.15 volts rms for a full-scale meter reading, regardless of the input signal level. The internal impedance at the OUTPUT terminal is 50 ohms over the full frequency range. High-impedance loads (above 100K) will not adversely affect the accuracy of the voltmeter. This output is valuable for increasing the sensitivity of bridges, etc., where distortion added to the waveform is not a factor.

1-8. The voltmeter chassis is constructed of aluminum alloy throughout. The panel is finished in non-reflecting, light-grey baked enamel; the cabinet is finished in dark-blue, baked wrinkle paint. The cabinet is equipped with rubber feet and a leather carrying handle. Control markings on the front panel are engraved and black filled. INPUT and OUTPUT terminals are special binding posts which accept either bare wire or banana plugs; the 3/4-inch spacing between binding posts accepts standard dual-banana plugs. The "ground" side of the INPUT and OUTPUT terminals is connected to the instrument chassis which is in turn connected to the power line ground through the third (round) prong of the plug on the power cable.

1-9. The voltmeter is equipped with a non-detachable power cord. Test leads, which may be plain wire leads or coaxial cable, and test probes must be supplied by the user.

1-10. Instruments designated Models 400DR, 400HR, and 400LR are rack mount configurations of the 400D, 400H, and 400L, respectively. They are identical to their cabinet model counterparts in every other respect. They are designed to be mounted in a standard 19 inchwide x7 inch high relay rack space. Refer to Appendix C for Replacement Parts information.

1-11. ACCESSORIES.

1-12. Accessory instruments for the voltmeter are available (not supplied) to increase its range of operation and application, such as increasing voltage measurement range and input impedance, converting to current measurement, providing line matching, etc., as follows:

a. H-P 11004A Line Matching Transformer. Provides balanced 135-ohm or 600-ohm input, 5 kc to 600 kc.

b. H-P 11005A Bridging Transformer. Allows voltage measurement on balanced lines. 20 cps to 45 kc.

c. H-P 11039A Capacitive Voltage Divider. Safely measures power-frequency voltages to 25 kilovolts. Division ratio, 1000:1. Input capacity, 15 pf \pm 1 pf.

d. H-P 11041A Capacitive Voltage Divider. Accuracy \pm 3%. Division ratio, 100:1. Input impedance, 50 megohms, resistive, shunted with 2.75 pf capacity. Maximum voltage, 1500 volts.

e. H-P 456A AC Current Probe. Allows current measurements without breaking the circuit. Sensitivity 1 mv/ma \pm 2% at 1 kc. Maximum input 1 amp rms; 2 amp peak. Output noise less than 50 μ v rms.

f. H-P 11029A-11034A Shunt Resistors. For measuring currents as small as 1 microamp full scale. Accuracy \pm 1% to 100 kc, \pm 5% to 4 mc (470A, \pm 5% to 1 mc). Maximum power dissipation, 1 watt.

SECTION II

INSTALLATION

2-1. UNPACKING AND INSPECTION.

2-2. There are no special precautions for unpacking the voltmeter. Save the shipping carton and packing materials for possible storage or reshipment. When unpacking, inspect instrument and packing materials for signs of damage in shipment. Make an operation check as directed in paragraph 2-10 to determine if performance is satisfactory. If there is any indication of damage, immediately file a claim with the transport service used or other cognizant authority.

2-3. LINE VOLTAGE REQUIREMENT.

2-4. The voltmeter is wired at the factory for use on 115-volt a-c power. This voltage may vary $\pm 10\%$ without adverse effect upon voltmeter performance. The voltmeter can be wired for use on 230-volt a-c power by reconnecting the dual primary windings on the power transformer as shown in the schematic diagram in Section V. When using 230-volt power, change from a 1-amp to a 1/2-amp slow-blow fuse. If necessary, provide an adapter for attaching the standard 115-volt plug on the voltmeter to the 230-volt outlet.

2-5. POWER LINE CONNECTION.

2-6. The three-conductor power cable on the voltmeter is terminated in a polarized three-prong male connector. The third contact is an offset round pin added to a standard two-blade connector, which grounds the instrument chassis when used with the appropriate receptacle. To connect this plug in a standard two-contact receptacle, use an adapter. The chassis ground connection is brought out of the adapter in a green pigtail lead for connection to a suitable ground.

2-7. The power plug normally supplied with the voltmeter is made of molded rubber and is an integral part of the power cable. On certain military contracts, a modification of the Model 400D, termed the H02-400D, is equipped with a removable plug having the same pin configuration but constructed of corrosion-resistant material. In all other respects the H02-400D is the same as the Model 400D and carries the same Federal Stock Number.

WARNING

The lower INPUT and OUTPUT signal terminals on the panel of the voltmeter are connected directly to the chassis of the voltmeter. Any voltage applied to the lower terminal will be shorted directly to ground. If the ground connection in the power cord is disconnected by use of an adapter, the entire voltmeter cabinet will carry whatever potential is applied to the lower terminal and may be a hazard to the operator.

2-8. INSTALLATION.

2-9. The voltmeter is a portable instrument requiring no permanent installation. The voltmeter is for bench-top operation, standing on its rubber feet with its front panel near the vertical plane. A bail is provided for raising the front of the cabinet to obtain a better viewing angle.

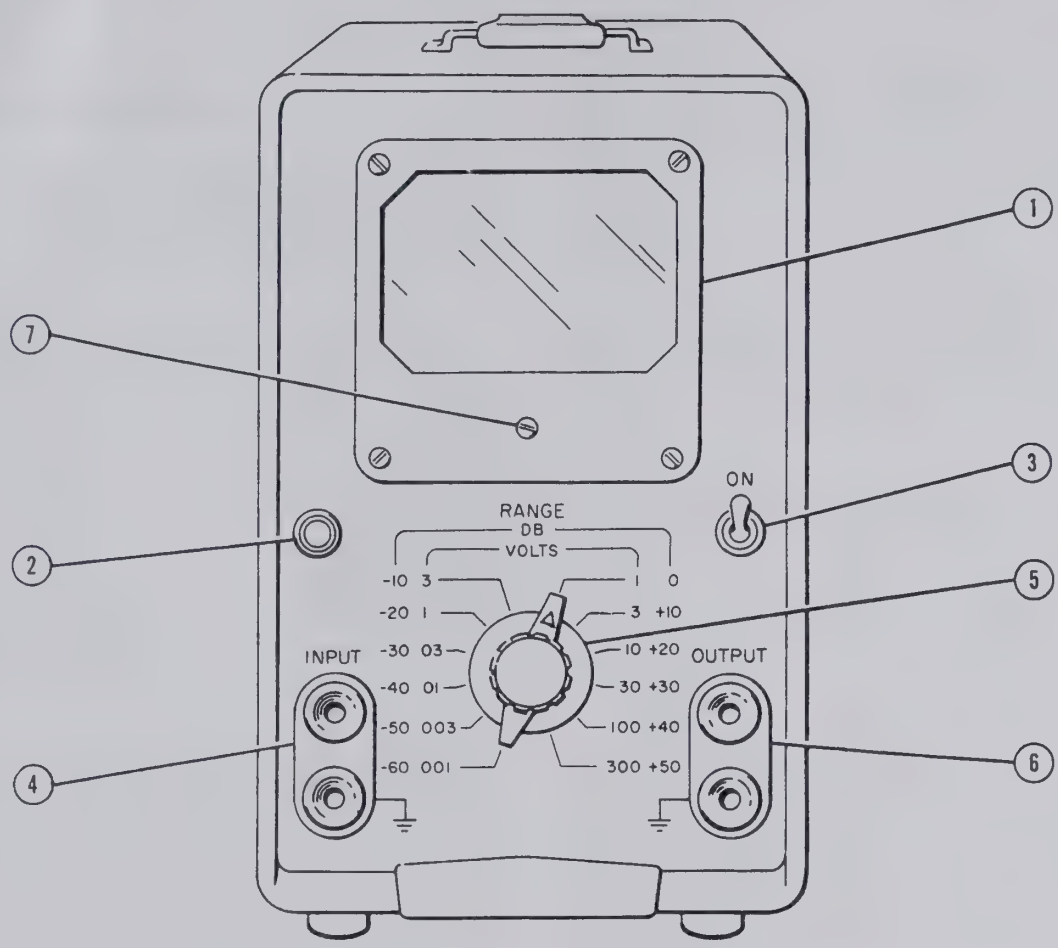
2-10. OPERATION CHECK.

2-11. The voltmeter is ready for use as received from the factory. The simple check described below can be made by incoming inspectors to determine if electrical damage was incurred in shipment. If more complete proof of instrument performance is required, the over-all performance check described in paragraph 5-22 must be used. Make a simple performance check as follows:

a. Connect voltmeter to the power line through a variable transformer. Set transformer for 115 volts, turn on and allow a five-minute warmup.

b. Measure any sine wave voltage, excepting the power line, from 0.01 to 300 volts whose exact voltage is known. Note that the lower INPUT terminal is connected to the power line ground.

c. While making the above measurement, adjust the line voltage from 103 to 127 volts. The reading on the meter must not change by more than the width of the pointer.



REFERENCE NUMBER	DESIGNATION	FUNCTION
1	Panel meter	Indicates rms volts and decibels of sine wave signals.
2	Indicator light	Indicates that voltmeter is turned on.
3	ON Power switch	Applies line power to voltmeter.
4	INPUT terminals	Receive voltage to be measured or signal to be amplified.
5	RANGE (DB-VOLTS) switch	Selects full-scale deflection sensitivity.
6	OUTPUT terminals	Supply signal level proportional to meter reading, with same waveform as applied to INPUT terminals.
7	Zero adjust screw	Meter zero adjust screw (for 400D and 400H only).

Figure 3-1. Voltmeter Front Panel, Showing Controls and Connectors

SECTION III

OPERATING INSTRUCTIONS

3-1. INSTRUMENT TURN-ON.

3-2. The voltmeter is ready for use as received from the factory and will give specified performance after a few minutes warmup. See Section II for information regarding connection to the power source and to the voltage to be measured. Controls are shown in figure 3-1.

3-3. GENERAL OPERATING INFORMATION.

3-4. **METER ZERO CHARACTERISTIC.** When the Model 400D and 400H Voltmeters are turned off, the meter pointer should rest exactly on the zero calibration mark on the meter scale. If it does not, zero-set the meter as instructed in paragraph 5-7. The meter supplied in the Model 400L Voltmeter is not provided with a mechanical meter zero adjustment. When the voltmeter is turned on with the INPUT terminals shorted, the meter pointer may deflect upscale slightly; this deflection does not affect the accuracy of a reading.

NOTE

When the voltmeter RANGE switch is set to the lowest ranges and the INPUT terminals are not terminated or shielded, noise pickup can be enough to produce up to full-scale meter deflection. This condition is normal and is caused by stray voltages in the vicinity of the instrument. For maximum accuracy on the .001-volt range, the voltage under measurement should be applied to the voltmeter through a shielded test lead.

3-5. **METER SCALES.** The two voltage scales on each of the voltmeter models are related to each other by a factor of $1:\sqrt{10}$ (10 db). In conjunction with the calibrated RANGE switch steps, this provides an intermediate range step spaced 10 db between "power of ten" ranges, which are 20 db apart. The relationship of the DECIBELS scale to the 0 to 1 VOLT scale is determined by making 0 db on the DECIBELS scale equal to the voltage required to produce 1 milliwatt in 600 ohms (0.775 volts). Thus, the DECIBELS scale reads directly in dbm (decibels referred to one milliwatt) across a 600-ohm circuit, and can be used to measure absolute level of sine wave signals. It can also be used to measure relative levels of any group of signals which have the same waveform, across any constant circuit impedance. The RANGE switch changes voltmeter sensitivity in 10-db steps accurate to within $\pm 1/8$ db. The RANGE switch position indicates the value of a full-scale meter reading.

3-6. **CONNECTIONS.** Voltmeter test leads must be provided by the user. The type of leads and probes used will depend upon the application, as listed below:

a. For connection to low-impedance signal sources, plain wire leads often are sufficient.

b. For high-impedance sources, or where noise pickup is a problem, low-capacity shielded wire must be used with a shielded, dual banana plug for connection to the voltmeter terminals.

c. If a probe is used, it should also be shielded to prevent pickup from the hand.

d. For signals above a few hundred kilocycles, the capacity of the test leads must be kept to a minimum by using very short leads, preferably unshielded. An alligator clip should be used at the test end so that connection can be made without adding the capacity of the user's hands.

3-7. **MAXIMUM INPUT VOLTAGE.** Do not apply more than 600 volts dc to the INPUT terminals. To do so exceeds the voltage rating of the input capacitor.

3-8. If an applied voltage momentarily exceeds the selected full-scale voltmeter sensitivity, a few seconds may be required for circuit recovery, but no damage will result.

3-9. **INPUT VOLTAGE WAVEFORM.** The voltmeter is calibrated to indicate the root-mean-square value of a sine wave; however, meter pointer deflection is proportional to the average value of whatever waveform is applied to the input. If the input signal waveform is not a sine wave, the reading will be in error by an amount dependent upon the amount and phase of the harmonics present, as shown in figure 3-2 below. When harmonic distortion is less than about 10%, the error which results is negligible.

INPUT VOLTAGE CHARACTERISTICS	TRUE RMS VALUE	METER INDICATION
Fundamental = 100	100	100
Fundamental +10% 2nd harmonic	100.5	100
Fundamental +20% 2nd harmonic	102	100-102
Fundamental +50% 2nd harmonic	112	100-110
Fundamental +10% 3rd harmonic	100.5	96-104
Fundamental +20% 3rd harmonic	102	94-108
Fundamental +50% 3rd harmonic	112	90-116

Note: This chart is universal in application since these errors are inherent in all average-responding type voltage-measuring instruments.

Figure 3-2. Effect of Harmonics on Voltage Measurements

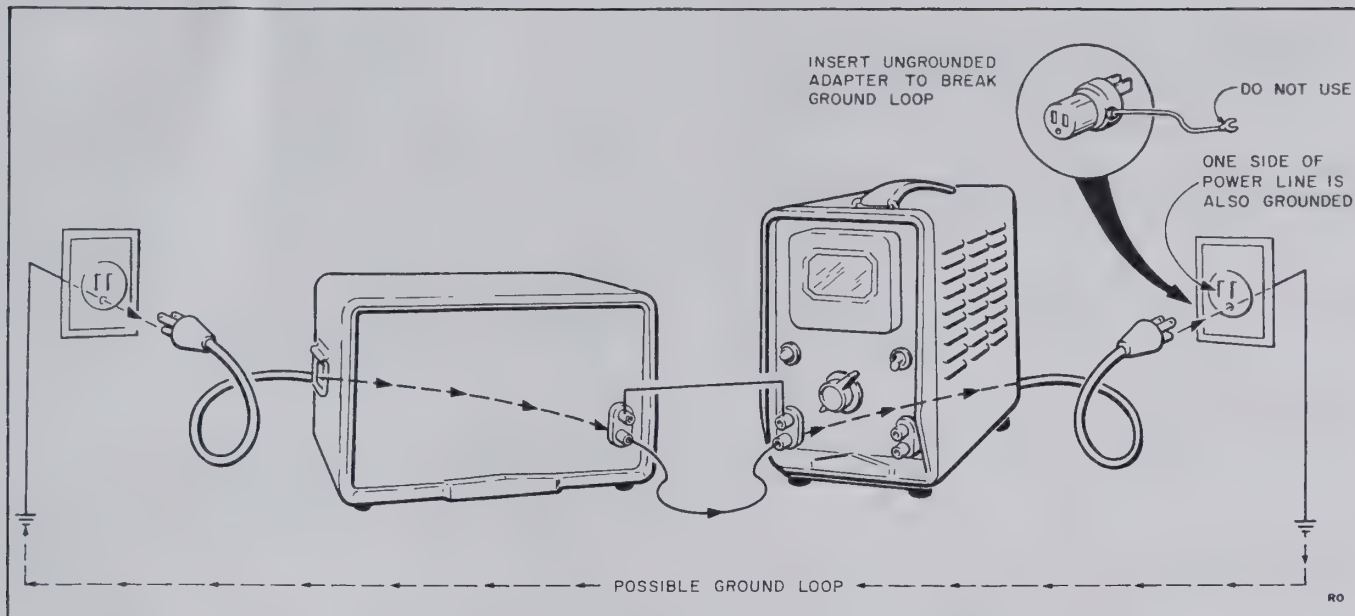


Figure 3-3. Test Setup for Avoiding Ground Loop

3-10. Since the voltmeter meter deflection is proportional to the average value of the input waveform, it is not adversely affected by moderate levels of random noise. The effect that noise has on the accuracy of the meter reading depends upon the waveform of the noise and upon the signal-to-noise ratio. A square wave has the greatest effect, a sine wave intermediate effect, and "white" noise has the least effect on the meter reading.

3-11. If the noise signal is a 50% duty cycle square wave and the signal-to-noise ratio is 10:1 (between peak voltages), the error will be about 1% of the meter reading. If the noise signal is "white" noise and the signal-to-noise ratio 10:1, the error is negligible.

3-12. LOW-LEVEL MEASUREMENTS AND GROUND CURRENTS.

3-13. When the voltmeter is used to measure signal levels below a few millivolts, ground currents in the meter test leads can cause an error in meter reading. Such currents are created when two or more ground connections are made between the instruments of a test setup and/or between the instruments and the power line ground. Two ground connections complete an electrical circuit (ground loop) for the voltages which are generated across all instrument chassis by stray fields, particularly the fields of transformers. These ground currents can be minimized by disconnecting the ground lead in the power cord from either the voltmeter or the signal source being measured, at the power outlet as shown in figure 3-3, and by making sure that in the test setup no other ground loop is formed that can cause a ground current to flow in the voltmeter test leads. Although the resultant voltage developed across a test lead is in the order of microvolts, it is enough to cause noticeable errors in measurements of a few millivolts. The presence of ground currents can sometimes be determined by simply changing the grounds for the instruments in the

setup and watching for a change in meter reading. If changing the ground system causes a change in meter reading, ground currents are present.

3-14. MEASUREMENT OF VOLTAGE.

3-15. The meter has two VOLTS scales, 0 to 1 and 0 to 3. When the RANGE switch is set to .001, .01, .1, 1, 10, or 100 VOLTS, read the 0 to 1 scale. When the RANGE switch is set to .003, .03, .3, 3, 30, or 300 VOLTS, read the 0 to 3 scale.

CAUTION

The lower (black) signal INPUT and OUTPUT terminals and the instrument case are connected to the power system ground when the instrument is used with a standard three-terminal (grounding) receptacle. Connect only ground-potential circuits to the black INPUT and OUTPUT terminals.

3-16. Operate the instrument as follows:

- Connect the voltmeter to the a-c power source.
- Turn the Power switch ON and allow a warmup period of approximately five minutes.
- Disconnect any external equipment from the OUTPUT terminals.
- Set the RANGE switch to the VOLTS range which will read the voltage to be measured at mid-scale or above. If in doubt, select a higher VOLTS range.
- Connect the voltage to be measured to the INPUT terminals.

CAUTION

AVOID A SHORT CIRCUIT ACROSS THE POWER LINE! To measure power line voltage, first connect only the upper (red) INPUT terminal to each side of the power line, in turn, leaving it connected to the side that causes meter indication. Then connect the lower (black) INPUT terminal (grounded internally) to the other side of the line. If this procedure is not followed, the power line may be short-circuited through the grounded INPUT terminal of the voltmeter.

f. Read the meter indication on the appropriate VOLTS scale, in accordance with the full-scale value indicated on the RANGE switch. Evaluate the reading in terms of the full-scale value indicated on the RANGE switch. Study the following examples:

Example 1

When the RANGE switch is in the .1 VOLTS range, read the 0 to 1 VOLTS scale. If the meter indicates .64 on that scale, the voltage being measured is:

$$.64 \text{ (meter indication)} \times \frac{.1 \left[\begin{array}{c} \text{switch-selected} \\ \text{voltage range} \end{array} \right]}{1 \text{ (full-scale value)}} = .064 \text{ volt}$$

Example 2

When the RANGE switch is in the 30 VOLTS range, read the 0 to 3 VOLTS scale. If the meter indicates 1.6 on that scale, the voltage being measured is:

$$1.6 \text{ (meter indication)} \times \frac{30 \left[\begin{array}{c} \text{switch-selected} \\ \text{voltage range} \end{array} \right]}{3 \text{ (full-scale value)}} = 16 \text{ volts}$$

3-17. MEASUREMENT OF DECIBELS.

3-18. The DECIBELS meter scale is provided for measuring dbm directly across 600 ohms and for measuring db ratio for comparison purposes when each measurement is made across the same circuit impedance. To measure signal level directly in dbm (0 dbm equals 1 milliwatt into 600 ohms) proceed as follows:

- Connect the voltmeter to the a-c power source.
- Turn the Power switch ON and allow a warmup period of approximately five minutes.
- Disconnect any external equipment from the OUTPUT terminals.
- Set the RANGE switch to the DB range which will give an upscale reading of the signal to be measured. If in doubt, select a higher-level scale.
- Connect the voltage to be measured to the INPUT terminals.

f. Note the meter indication on the DECIBELS scale (-12 to +2 db). The signal level is the algebraic sum of the meter indication and the db value indicated by the RANGE selector. Study the following examples:

Example 1

If the indication on the DECIBELS scale is +2 and the RANGE switch is in the +20 DB position, the level is +22 dbm.

Example 2

If the indication on the DECIBELS scale is +1.5 and the RANGE switch is in the -40 DB position, the level is -38.5 dbm.

3-19. To measure db across impedances other than 600 ohms, follow the above procedure and evaluate the results as follows:

NOTE

Since the measurement is made across other than 600 ohms, the level obtained in step f is in db, but not in dbm.

a. To obtain the difference in db between measurements made across equal impedances, algebraically subtract the levels being compared.

b. To obtain the reading of a single measurement in dbm, note the impedance across which the measurement is made and refer to the Impedance Correction Graph, described in paragraph 3-20.

c. To obtain the difference in dbm between measurements made across different impedances, convert each measurement to dbm using the Impedance Correction Graph described in paragraph 3-20. Then algebraically subtract the dbm levels being compared.

3-20. IMPEDANCE CORRECTION GRAPH.

3-21. As the voltmeter DECIBELS scale is calibrated to indicate dbm for measurements made across 600-ohm circuits, a correction factor must be used when measurements are made across circuit impedances other than 600 ohms, if absolute dbm levels are desired. The correction factor is not necessary in measuring relative db levels (not dbm) across the same impedance, but it is required for comparison of db levels measured across different impedances. The Impedance Correction Graph in figure 3-4 gives the correction factor for conversion of the meter reading to dbm when the impedance of the circuit under test is known. To use the graph, read the conversion factor corresponding to the test circuit impedance and add it to the meter reading determined by the method of paragraph 3-17. Observe the algebraic sign of the correction factor in making the algebraic addition. Use the following examples:

Example 1

If the measurement is made across 90 ohms, the indication on the DECIBELS scale is +2, and the RANGE switch is at the +30 DB position, the level in dbm is obtained as follows:

+ 2 (meter indication)	
+30 (RANGE switch position)	
+32 (sum)	
+ 8 (correction factor from the Impedance	
+40 dbm	Correction Graph)

Example 2

For the same conditions as given above, except that the measurement is made across an impedance of 60,000 ohms, the level in dbm is obtained as follows:

+ 2 (meter indication)	
+30 (RANGE switch position)	
+32 (sum)	
-20 (Correction factor from the Impedance	
+12 dbm	Correction Graph)

3-22. USE OF VOLTMETER AMPLIFIER.

3-23. The amplifier in the voltmeter may be used for amplifying weak signals. With full-scale meter deflection, the open-circuit output of the amplifier is approximately 0.15 volt rms regardless of the RANGE switch position. The impedance looking into the OUTPUT terminals is approximately 50 ohms. The frequency

response and calibration of the voltmeter may be affected by the impedance of a load applied to the OUTPUT terminals. To check the effect of the applied load: observe the meter reading obtained with no load connected to the OUTPUT terminals and then note any shift of reading when the external circuit is connected to the OUTPUT terminals. If the shift is negligible, the measurement is not being affected appreciably by the load. Whenever the input signal is changed, i.e., a different frequency or band of frequencies is applied, repeat the quick check described above.

3-24. Maximum gain from the amplifier is obtainable only on the lowest (.001 volts) range, since output level is the same for all bands. This is due to the 10-db amplification loss per step inserted by the RANGE switch as it is turned clockwise. Amplification may also be obtained on the .003, .01, .03, and 1 volt ranges.

3-25. When the voltmeter is used as an amplifier, select a range which gives a meter deflection near full scale. Off-scale signals more than twice the value of the position of the RANGE switch will cause severe distortion.

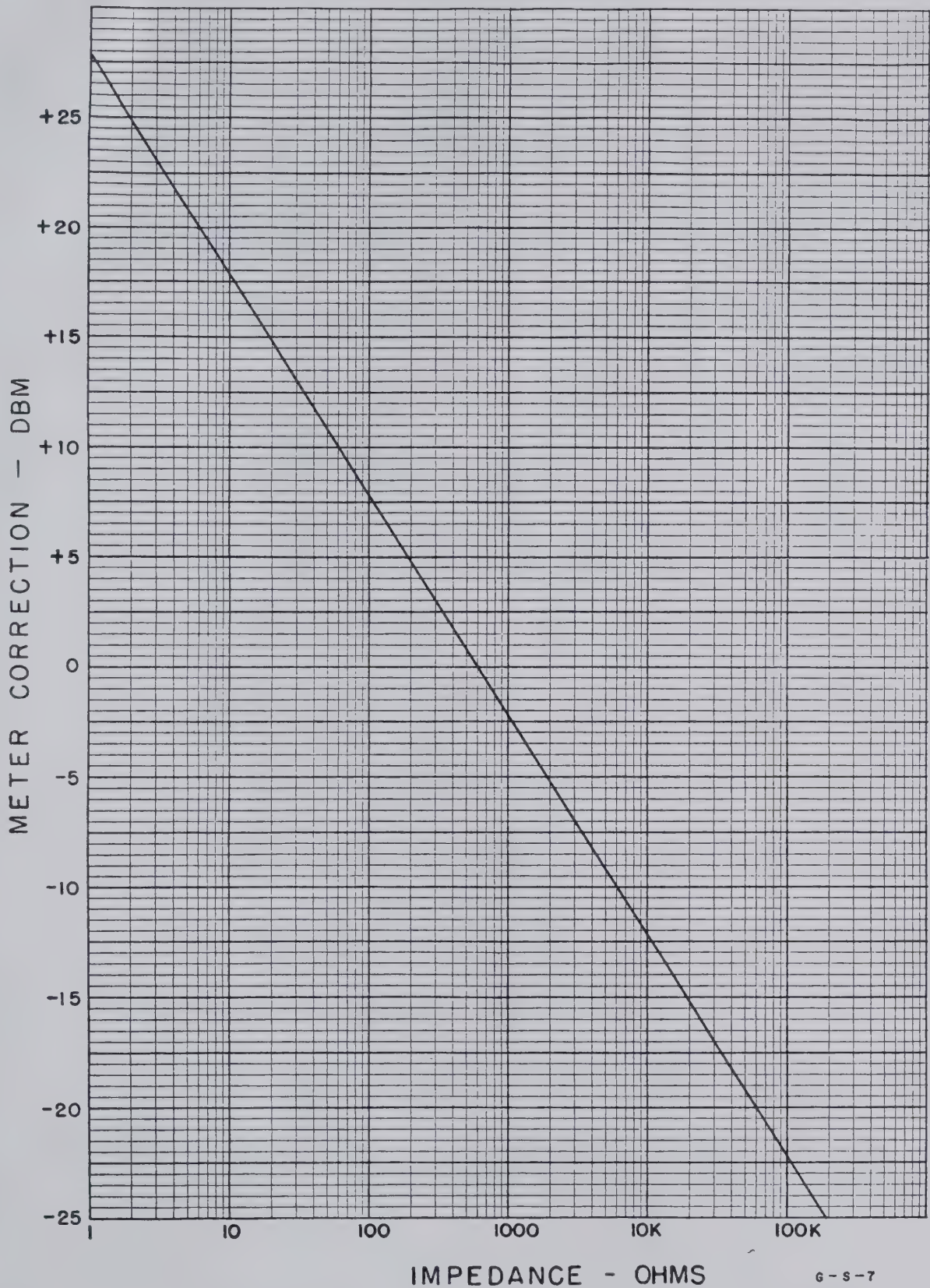


Figure 3-4. Impedance Correction Graph

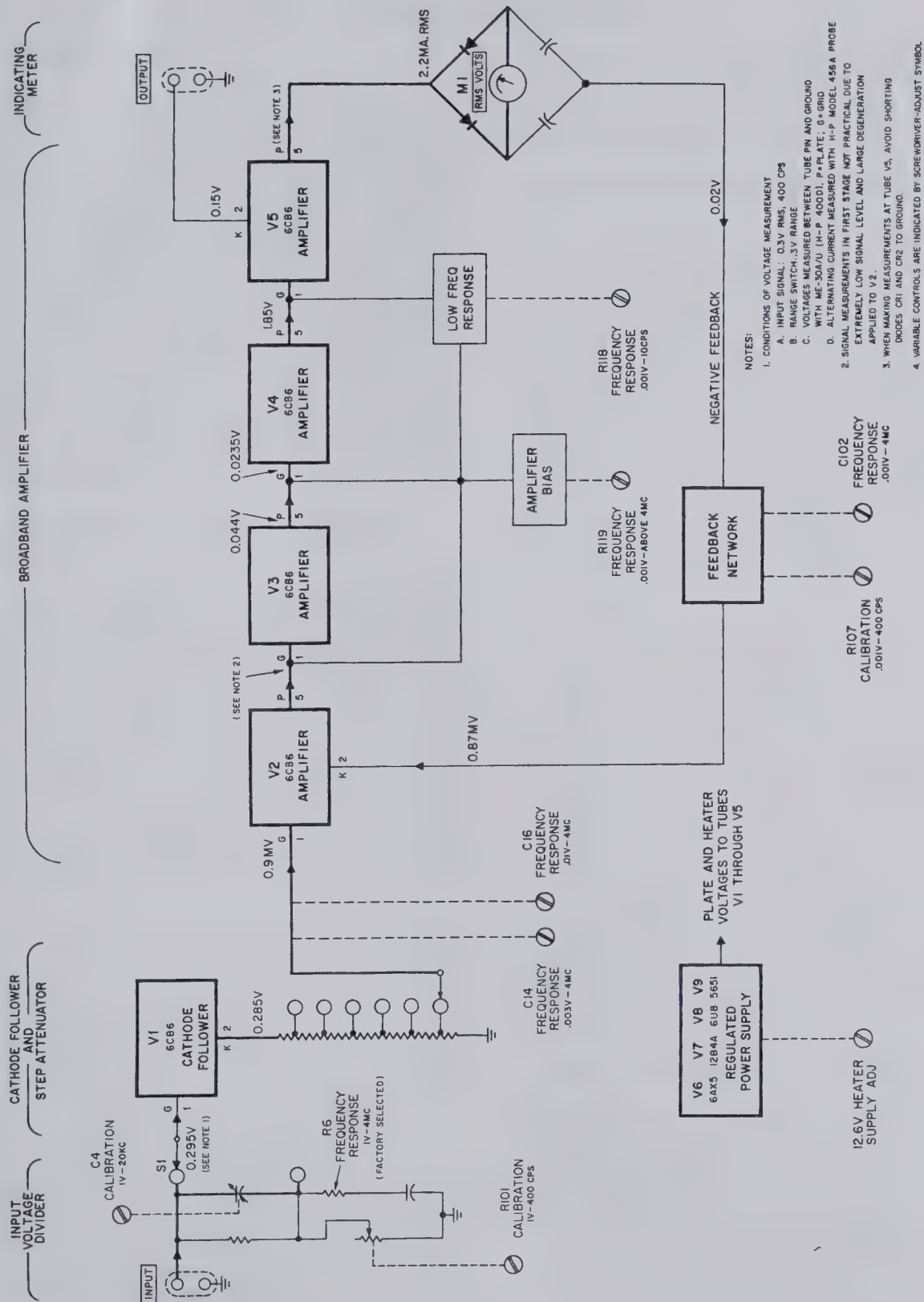


Figure 4-1. Voltmeter Block Diagram

SECTION IV

CIRCUIT DESCRIPTION

4-1. BLOCK DIAGRAM.

4-2. The electrical circuits of the voltmeter are shown in the block diagram in figure 4-1; they consist of an input voltage divider controlled by the RANGE switch, a cathode follower input tube, a precision step attenuator controlled by the RANGE switch, a broadband amplifier, an indicating meter, and a regulated power supply. The voltage applied to the INPUT terminals for measurement is divided by 1000 before application to the input cathode follower when the RANGE switch is set to the 1-volt range and higher; the input voltage is applied directly to the cathode follower on the lower ranges. The voltage from the cathode follower is divided in the precision attenuator to be less than 1 millivolt for application to the voltmeter amplifier. The output of the amplifier is rectified in a full-wave bridge rectifier with a d-c milliammeter across its midpoints. The resultant direct current through the meter is directly proportional to the input voltage.

4-3. INPUT VOLTAGE DIVIDER AND STEP ATTENUATOR.

4-4. The input voltage divider limits the signal level applied to the input cathode follower to less than 0.3 volt rms when voltages above this level are measured with the RANGE switch set at the 1-volt range or above. The divider consists of a resistive branch with one element made adjustable to obtain exact 1000:1 division at middle frequencies and a parallel capacitive branch with one element made adjustable to maintain exact 1000:1 division to beyond 4 megacycles. The input impedance of the voltmeter is established by this divider and is the same for all positions of the RANGE switch. On the six low-voltage positions of the RANGE switch, the input divider provides no attenuation of the input voltage. (See figure 5-10 for the complete schematic.)

4-5. The step attenuator in the cathode circuit of the input cathode follower reduces the voltage to be measured to 1 millivolt or less for application to the voltmeter amplifier. Each step of the attenuator lowers the signal level by exactly 10 db ($1:\sqrt{10}$). The attenuator consists of six precision wirewound resistors which are selected to very high accuracy and carefully mounted on a 12-position rotary switch. The RANGE switch rotor has two contactors (see figures 5-9 and 5-10); the first contacts each resistor in turn while the input divider is in the non-attenuating position; the second rotor finger repeats these contacts while the input attenuator is in the attenuating position. On the .001-volt range a fixed capacitor (C15) is automatically connected to provide flat frequency response beyond 4 megacycles. In the .003- and the .01-volt ranges, separate adjustable capacitors (C14, C16) are automatically connected to the attenuator to permit setting the frequency response at 4 megacycles. C14 and C16 are also connected to the attenuator on the 3- and 10-volt ranges. Fixed capacitor C106 (permanently connected) flattens frequency response on the .03- and 30-volt ranges.

4-6. Cathode follower V1 provides a constant, high input impedance to the input voltage divider and INPUT terminals of the voltmeter and provides a relatively low impedance in its cathode circuit to drive the step attenuator. The voltage gain factor across V1 is 0.95.

4-7. BROADBAND VOLTMETER AMPLIFIER.

4-8. Amplification of the signal voltage is provided by a four-stage stabilized amplifier consisting of tubes V2 through V5 and associated circuits. The amplifier provides between 55- and 60-db gain with about 55 db of negative feedback at mid-frequencies. The feedback signal is taken from the plate of the output amplifier (V5) through the meter rectifiers and gain-adjusting circuit to the cathode of the input amplifier (V2). Variable resistor R107 in the feedback network adjusts the negative feedback level to set the basic gain of the amplifier at mid-frequencies, while adjustable capacitor C102 permits setting amplifier gain at 4 megacycles. Variable resistor R118 in the coupling circuit between V4 and V5 permits adjusting the gain of the amplifier at 10 cycles per second by controlling the phase shift of low-frequency signals between these two stages (increasing phase shift decreases degeneration and increases gain).

4-9. Variable resistor R119 in the grid return path for V3, V4, and V5 adjusts the total transconductance of these tubes in order to restrict the maximum gain-bandwidth product of the amplifier. The gain-bandwidth product must be restricted to give a smooth frequency response rolloff above 4 megacycles and to prevent possible unstable operation at frequencies far above 4 megacycles when tubes having unusually high transconductance are used (tube transconductance tolerances during manufacture permit wide variations in new tubes; the adjustment permits the use of such tubes). The plate voltage from V5 is rectified by the meter rectifiers and drives the feedback network. The cathode voltage of V5 is fed to the meter OUTPUT terminals for monitoring purposes. The current through V5, and thus the signal voltage at the cathode, is affected by the loading of the meter rectifiers. For signal levels causing third-scale or more meter deflection, this distortion consists of a very small irregularity near 0 volts on the waveform as each diode begins conduction.

4-10. INDICATING METER CIRCUIT.

4-11. The meter rectifier circuit consists of two silicon diodes and two capacitors connected as a bridge with the indicating meter across the mid-points as shown in figure 4-2. The diodes provide full-wave rectification of the signal current for operating the meter. Electron flow through the meter is supplied in the following manner (see figure 4-2). During the positive-going half cycle of plate voltage on V5, rectifier CR1 conducts electrons from both C32 and C33 back to the B+ buss. The portion of electrons from C33 flows through the meter on the way to B+. At this point in the cycle, both C32 and C33 are charged to the potential of B+ less some small drop in R51 and R52.

4-12. During the negative-going half cycle of the plate voltage of V5, rectifier CR2 conducts electrons back to both C32 and C33 from the plate of V5. That portion of electrons going back to C32 flows through the meter on the way (in the same direction that the electrons flowed in the first, positive, half cycle). At this point in the cycle, both C32 and C33 are discharged. The pulsating current through the meter is smoothed by C34 to prevent meter pointer vibration when measuring low-frequency signals. The current is proportional to the arithmetic average value of the waveform amplitude of the signal. Meter calibration in rms volts is based on the mathematical ratio between the average and rms values of true sine wave current.

4-13. In addition, the bridge serves as a segment of a voltage divider (in series with L11 and R108) connected across the output of the amplifier. The negative feedback voltage fed to the input of the amplifier is obtained across L11 and R108. The alternating charge and discharge of C32 and C33 produce at their junction with L11 an alternating current of the same phase and waveform as that at the plate of V5. This phase is negative with respect to the input signal applied to the first stage of the amplifier (V2), and drives the negative feedback network.

4-14. POWER SUPPLY.

4-15. The power supply consists of tubes V6 through V9 and the associated circuits, as shown in the complete

schematic diagram, figure 5-10. The power supply furnishes regulated +250V d-c voltage for the grid and plate bias circuits of tubes V1 through V5, unregulated 12.6V d-c voltage for the heater supply of tubes V1 through V4, and 6.3V a-c voltage for the heater supply of tubes V5 through V8. The power supply is designed to operate from either a 115-volt ($\pm 10\%$) or a 230-volt ($\pm 10\%$) a-c power source of 50 to 1000 cps. The primary winding of power transformer T1 is arranged in two sections, which can be strapped either in parallel or in series, to permit operation on 115V or 230V, respectively.

4-16. The output of rectifier V6 is applied to the voltage regulator circuit consisting of V7 through V9 which supplies a constant, +250 volts dc to the stabilized amplifier circuit of the voltmeter. Tube V7 is the series regulator tube, and V9 provides a fixed reference voltage drop, with which the output voltage is compared in amplifier V8B. V8A is a cathode follower which couples the reference voltage from V9 to V8B without loading V9. The regulated output voltage is applied to the control grid of V8B, while the reference voltage is applied to its cathode. The difference between the control grid and cathode voltages controls the operating point of V8B and thus its plate voltage, which in turn supplies the grid voltage for regulator V7. Any change in the regulated output of V7 produces a correcting change in the grid bias of V7 through the action of V8B, thus maintaining an essentially constant output voltage despite changes in line voltage or load on the supply. The gain of V8B is high enough to keep the output at the V7 cathode regulated

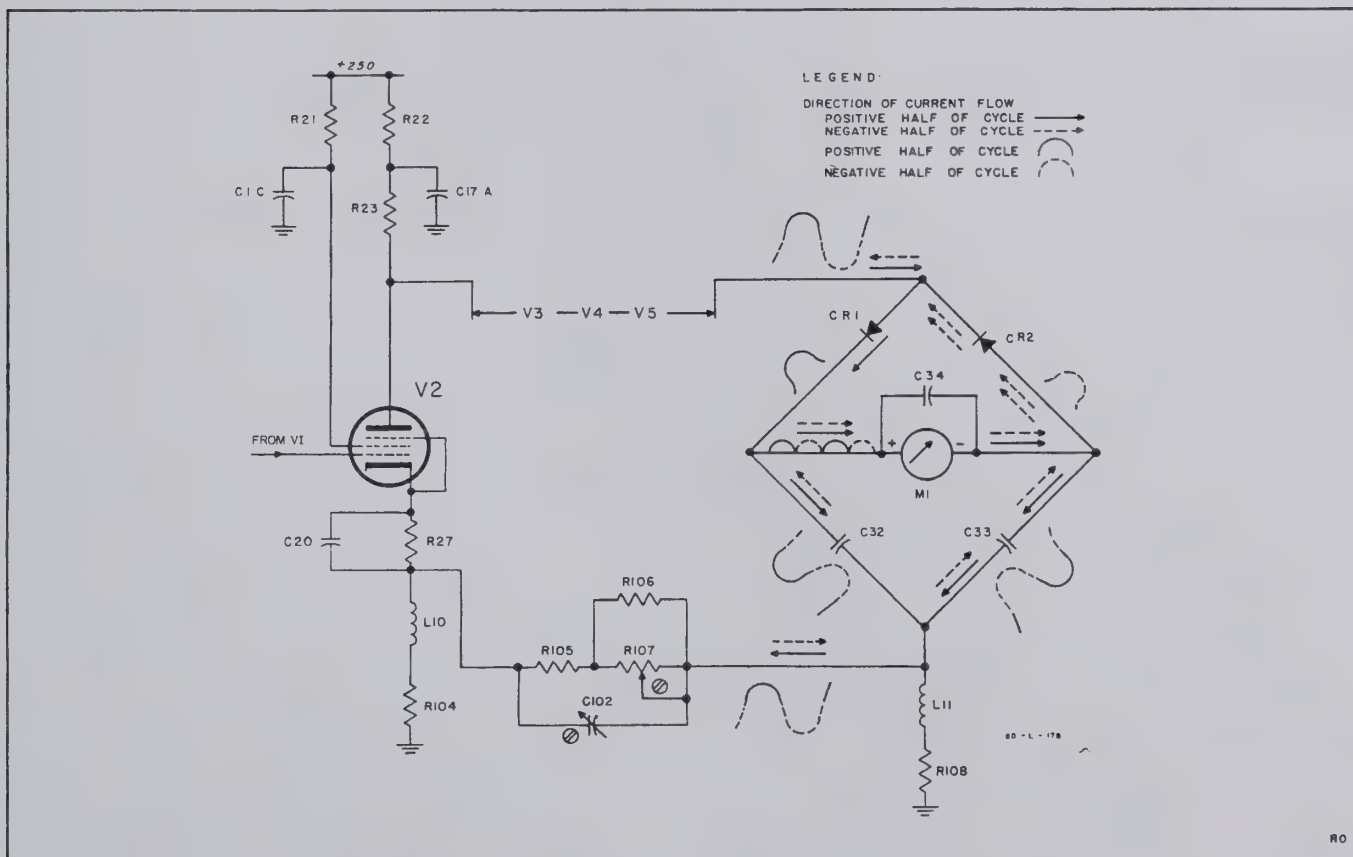


Figure 4-2. Simplified Schematic of Meter Bridge Circuit

to within ± 1 volt dc as the V7 plate voltage is varied $\pm 10\%$, with about 60 ma of load current. The response of the regulating circuits is fast enough to reduce ripple in the output voltage to less than 1 millivolt, supplementing the filtering action of C30. C36 couples the ripple component in the regulated output directly to V8B to avoid attenuation in R62. R57 shunts a small portion of the load current around V7 to prevent excessive V7 plate dissipation at high line voltages. R63 and C35 constitute a low-pass filter which prevents noise generated in V9 from reaching V8B.

4-17. The heater supply for the voltmeter tubes is divided into two sections. One section supplies d-c voltage for the tubes in the input cathode follower and

the amplifier. The other section supplies a-c voltage for the tubes in the power supply. The voltage required for the heaters of tubes V1 through V4 is obtained from 6.3V and 7.3V secondary windings of transformer T1, which are series connected. The voltage developed across the two series-connected windings is rectified by full-wave rectifier CR3, reduced to 12.6 volts by R66 and R68 in parallel, and applied to the series-parallel-connected heaters of V1 through V4, as shown in figure 5-10. The series-parallel connection of the four heaters establishes a voltage of 6.3V for each. The heater of V5 receives 6.3V ac from one of the windings which drives CR3. The heaters of V6, V7, and V8 receive 6.3V ac from a separate 6.3V secondary winding on T1.

SECTION V

MAINTENANCE

5-1. SCOPE.

5-2. This section contains complete instructions for repairing and calibrating the voltmeter. This material is covered in the following groups of paragraphs:

Lead Paragraph	Topic
5-3.	Precautions
5-5.	Test Equipment Required
5-7.	Meter Zero Adjustment
5-9.	Cabinet Removal
5-10.	Tube Replacement
5-13.	Replacement of Special Parts
5-17.	Trouble Shooting
5-20.	Testing the Power Supply
5-22.	Testing Voltmeter Performance
5-24.	Calibration and Frequency Response Adjustments

5-3. PRECAUTIONS.

5-4. Observe the following precautions:

a. Make no adjustments and replace no parts in the voltmeter except as described in one of the following

procedures. If an adjustment or replacement of parts is made without following instructions or understanding the effects, further trouble shooting may be complicated.

b. Do not remove tubes when the voltmeter is turned on. Before replacing tubes refer to paragraph 5-10.

5-5. TEST EQUIPMENT REQUIRED.

5-6. The test equipment required for complete testing of the voltmeter is listed in figure 5-1. Equivalent instruments may be substituted for those listed.

5-7. METER ZERO ADJUSTMENT.

5-8. The meter is properly zero-set when its pointer rests over the zero calibration mark on the meter scale when the instrument is 1) at normal operating temperature, 2) in its normal operating position, and 3) turned off. Adjust the zero-set if necessary, as follows:

a. Allow the voltmeter to operate for 20 minutes so that the meter movement will reach normal operating temperature.

b. Turn the voltmeter off and allow one minute for all capacitors to discharge.

INSTRUMENT TYPE	REQUIRED CHARACTERISTICS	USE	DESIGNATION
Electronic Multimeter	0 to 300 a-c and d-c volts; accuracy of $\pm 3\%$ or better; input impedance 100 megohms.	Voltage and resistance measurement.	ME-26B/U or H-P 410B
Oscillator	10 cps to 300 kc; 3 volts output into 50-ohm load.	Signal source for testing and calibration	H-P 200S
Voltmeter Calibrator (Precision Voltage Source)	400-cps output voltage; 0.001 to 300 volts in 10-db steps $\pm 0.2\%$; 0.1 to 1.0 volt in 0.1 volt steps $\pm 0.2\%$.	Calibrating voltmeter at mid-frequencies.	H-P 738BR
Frequency Response Test Set	300-kc to 4-mc range; 3 volts output into 50-ohm load; 10-db steps, 0 to 70 db.	Calibrating voltmeter frequency response.	H-P 739A
Oscilloscope or AC Voltmeter	10-cps to 4-mc range.	Trouble shooting by signal tracing.	H-P 160B or H-P 400D
Variable Transformer	Adjust line voltage between 103 and 127V ac with 1-amp load.	Checking voltmeter operation with varying line voltage.	CN-16/U or Ohmite VT2
D-C Current Test Set (Milliammeter)	Clip-on type measurement; current range up to 100 ma.	Checking load on power supply.	H-P 428B

Figure 5-1. Test Equipment Required

c. Rotate mechanical zero-adjustment screw clockwise until meter pointer is to the left of zero and moving upscale toward zero.

d. Continue to rotate adjustment screw clockwise; stop when pointer is exactly on zero. If pointer overshoots zero, repeat steps c and d.

e. When pointer is exactly on zero, rotate adjustment screw approximately 15 degrees counterclockwise. This is enough to free the zero adjustment screw from the meter suspension. If pointer moves during this step, because the adjustment screw is turned too far counterclockwise, repeat the procedure of steps c through e.

5-9. CABINET REMOVAL.

a. Remove the two cabinet retaining screws at the rear of the instrument.

b. Push the instrument chassis forward out of the cabinet. The bezel ring remains attached to the front panel.

c. When replacing cabinet, pull power cable through opening at rear of cabinet. Be sure power cable is not caught between chassis and cabinet. Replace retaining screws.

5-10. TUBE REPLACEMENT.

CAUTION

Do not remove tubes from the voltmeter when power is applied. To do so may damage the voltmeter.

5-11. In many cases instrument malfunction can be corrected by replacing a weak or defective tube. Check tubes by substitution while following the voltmeter

performance check procedure in paragraph 5-22. Results obtained through the use of a "tube checker" can be misleading. Before removing the tubes from the instrument, mark the original tubes so they can be returned to the same socket if they are not defective. Replace only those tubes proven to be defective.

5-12. Figure 5-2 lists each tube in the voltmeter with its function and the check or adjustment required if the tube is replaced.

5-13. REPLACEMENT OF SPECIAL PARTS.

5-14. PRECISION RESISTORS AND INDUCTORS. Several parts used in the voltmeter have closer tolerances than those used in most test equipment. Resistors R104, R105, R108, and R111 through R116 are precision components. If these resistors require replacement, use the same value and type as the original, as shown in the parts breakdown. If different values are used or component positions are moved, the calibration of the voltmeter may be inaccurate or the frequency response may be altered. The inductance of L10 and L11 affects the frequency response of the voltmeter. Do not alter the shape or position of these coils. Install replacement components in the same positions the original components occupied, as nearly as possible.

5-15. DIODE RECTIFIERS. Special high-performance silicon diodes selected by the Hewlett-Packard Co. are used for CR1 and CR2. When replacing the silicon diodes, be careful in soldering; heat can damage them. Place a heat sink (such as a long-nose pliers) on each diode lead close to the diode body to conduct the heat away. If CR1 and CR2 are replaced, the voltmeter calibration and frequency response must be checked as described in paragraph 5-22.

5-16. RANGE SWITCH. Because of the critical construction and wiring of switch S1, it is not practical to attempt a major repair on the switch. When mechanical failure occurs in switch S1, replace the complete

CIRCUIT REF.	TYPE	FUNCTION	CHECK OR ADJUSTMENT
V1	6CB6*	Cathode Follower	Calibration and frequency response (para. 5-22)
V2	6CB6	1st Amplifier	
V3	6CB6	2nd Amplifier	
V4	6CB6	3rd Amplifier	
V5	6CB6	4th Amplifier	
V6	6AX5	High Voltage Rectifier	Test of the power supply (para. 5-20)
V7	12B4A	Series Regulator	
V8	6U8	Control Tube	
V9	5651	Reference Tube	
* Note that V1 must be replaced by a 6CB6, aged and selected for low noise and microphonics (μ_p , Part No. 5080-0621).			

Figure 5-2. Adjustments Required When Tubes Are Replaced

switch assembly. Use the following procedure. (Locate parts by referring to figures 5-3 and 5-4; RANGE switch connections are shown in figure 5-9.)

- a. Remove voltmeter cabinet. (See paragraph 5-9.)
- b. Loosen setscrews in RANGE switch knob and remove knob.
- c. Disconnect capacitor C104 from switch S1.
- d. Disconnect white leads from capacitors C14 and C16. Label each lead with a tag.
- e. Remove the two screws and one nut which retain the switch shield plate.
- f. Disconnect white leads from switch contacts. Tag each lead to permit easy connection to the new switch.
- g. Disconnect the heavy dark-green switch lead, the heavy light-green switch lead, and the heavy black switch lead at terminal strips. Tag each lead.

NOTE

The input shield must be removed for access to the terminal board connection of the dark-green lead.

- h. Remove the nut which holds the switch bushing to the front panel.
- i. Remove RANGE switch assembly.
- j. The sequence for installing the replacement RANGE switch assembly is the reverse of the removal procedure.
- k. After replacement of switch S1, check the calibration and frequency response of the voltmeter and make necessary adjustments.

5-17. TROUBLE SHOOTING.

5-18. The first step in trouble shooting is to learn the nature of the symptoms of the malfunction with as much detail as possible. Inspect the test setup being used when symptoms of malfunction were observed, to be sure that the source of trouble is not external to the voltmeter. Then remove the voltmeter cabinet as directed in paragraph 5-9 and inspect the circuits of the voltmeter, looking for signs of overheating, deterioration, and physical damage or tampering. Check the fuse. If the fuse is blown, try another fuse to see if it blows; if it does, measure the d-c resistance of filter capacitors C1, C17, C30, C39, rectifier CR3, and the windings of transformer T1 to locate the short circuit without applying power to the voltmeter.

5-19. If the voltmeter can be turned on safely (without the fuse blowing), measure the line voltage applied to T1 and the voltmeter power supply output voltages (see paragraph 5-20). Check the tubes of the power supply if the regulated voltage is not the proper value or is unstable. Use the procedures of figure 5-5 and the tests described in paragraph 5-22 to learn the full nature of the trouble symptom. Watch for marginal

operation by operating the voltmeter at 103 and 127 line volts while making tests. Check the tubes in the voltmeter amplifier. Measure the tube element voltages at the tube sockets and compare readings with the values shown in the voltage and resistance diagram in figure 5-8. Apply a test signal to the input and measure the voltage of the test signal while tracing it through each coupling network and each stage of amplification. Compare readings with those shown in the block diagram, figure 4-1. In figure 4-1, an a-c current probe, H-P Model 456A, is recommended for the measurement of a-c current in the meter circuit without breaking any leads. If this current probe is not available, avoid measurement of the a-c current. Check meter indications as directed in paragraph 5-22 instead. An oscilloscope may be used for observing test signal waveshape and measuring amplitude, if desired.

5-20. TESTING THE POWER SUPPLY.

5-21. The regulated power supply produces a constant +250 vdc to operate all the tubes in the amplifier section. The stability of the voltmeter depends directly upon the stability of the +250 volts from the supply. When the supply is operating satisfactorily, the +250 volt output remains constant and the ripple level on it remains less than about 1 millivolt for line voltages between 103 and 127 volts. Weak tubes (V6, V7, and V8) are the usual causes of instability. An unstable regulator tube is indicated by excessive line frequency ripple and varying output voltage as the line voltage is changed. Marginal operation is indicated if a trouble symptom appears only when a low or high line voltage is applied. To test the complete power supply proceed as follows:

- a. Connect the voltmeter to an adjustable line transformer so the applied line voltage can be varied between 103 and 127 volts. Set line voltage to 115 volts, turn on the voltmeter, and allow a five-minute warmup period.

- b. Measure the d-c voltage between V6 (pin 8) and ground. Normal value is 410 ± 10 volts with exactly 115 volt power line input. Lower line voltage 10% to 103 volts for 2 minutes. If the d-c voltage slowly drops below 360 volts, replace V6.

- c. Measure the d-c voltage between V7 (pin 1) and ground with line voltage adjusted to 115 volts. Correct value is 250 ± 5 volts.

- d. Vary line voltage from 103 to 127 volts. The d-c voltage observed in step c must not change more than ± 1 volt. For wrong voltage and/or poor regulation, replace V7, V8 or V9.

- e. Measure the a-c voltage between V7 (pin 1) and ground. Ripple voltage must be less than 3 mv for any line voltage (103 to 127 volts). High ripple voltage is caused by defective V8, V7, V6 or V9. Replace in this order.

- f. Measure the direct current in the lead from V7 (pin 1) which must be less than 60 milliamperes. If the current is much too high, the regulator circuit will not function properly. Excessive current indicates

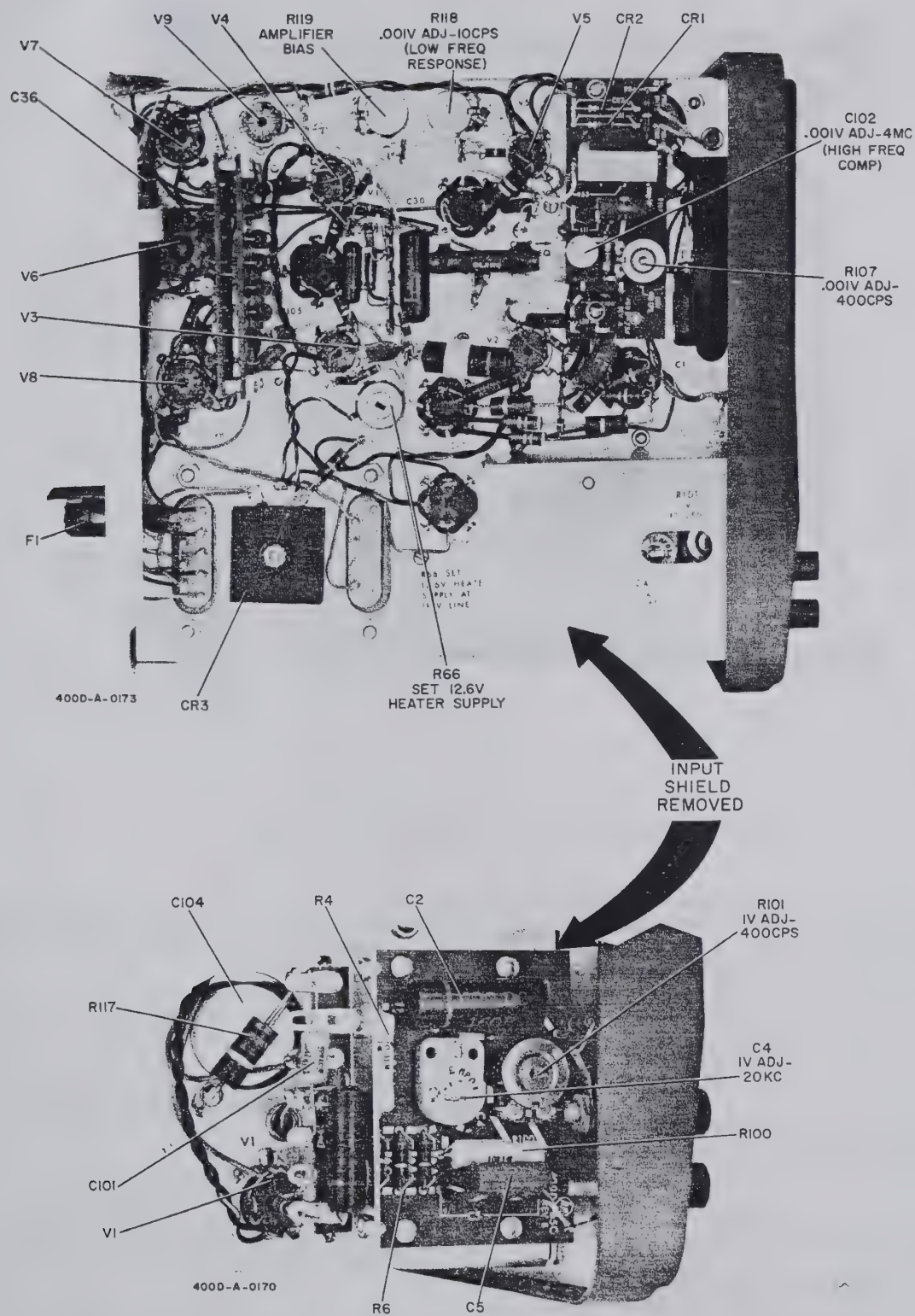


Figure 5-3. Left Side View of Voltmeter Chassis

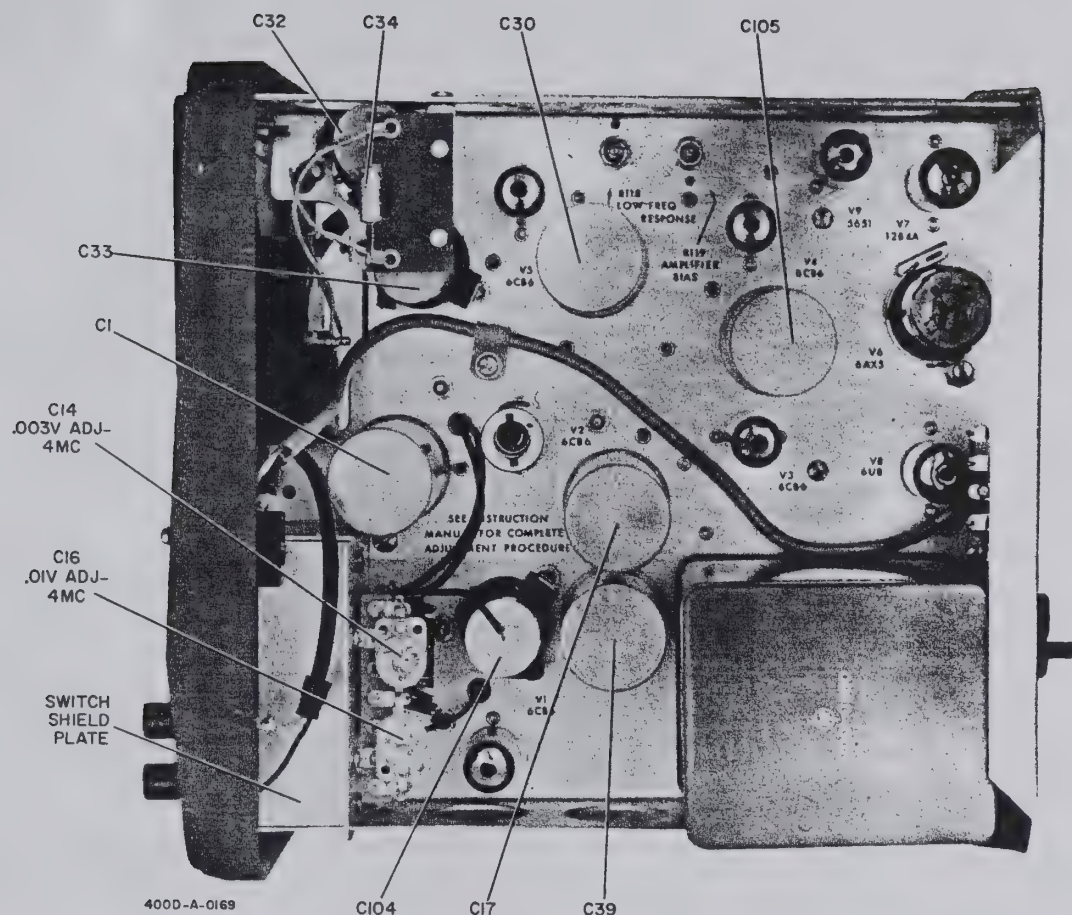


Figure 5-4. Right Side View of Voltmeter Chassis

a short circuit or partial short in the circuits of the voltmeter amplifier section. A clip-on type milliammeter should be used for this measurement.

g. If the output voltage is stable but is incorrect, measure the resistance of R62 and R64. The ratio of these two resistors determines what the output voltage will be. If the value of one of these resistors is incorrect and produces the wrong output voltage, replace it with a resistor which provides the correct output voltage.

h. Measure the d-c voltage across C39A which must be 12.6 volts with a line voltage of 115 volts. If necessary, adjust R66 to obtain 12.6 volts. If the voltage cannot be set to 12.6 volts, check the a-c voltage from the associated transformer windings; also check CR3 and C39.

5-22. TESTING VOLTMETER PERFORMANCE.

5-23. The following test procedure checks the accuracy and stability of the voltmeter at low and high frequencies

and with low and high line voltages. It can be used for comprehensive incoming inspection, for proof of performance, and for trouble shooting. If the readings are within specifications during these tests, the voltmeter is operating properly. This test is made without removing the cabinet. Instruments used to test the accuracy of the voltmeter (see paragraph 5-5) must be known to have sufficient accuracy to make valid measurements. Proceed as follows:

a. Connect the voltmeter as shown in figure 5-6. (This setup measures calibration accuracy at mid-frequencies.)

b. Set the line voltage to 115 volts, turn the voltmeter on and allow a 30-minute warmup period.

c. Check the instrument meter zero setting as instructed in paragraph 5-7.

d. Connect the voltmeter to the voltmeter calibrator; set voltmeter RANGE switch to .001, and set voltmeter calibrator VOLTAGE SELECTOR switch to provide 0 volts output.

TROUBLE	PROBABLE CAUSE	REMEDY
1. Power indicator lamp does not light.	a. Fuse F1 burned out. b. Power indicator lamp DS1 defective. c. Defective a-c power cable. d. Power switch S2 defective. e. Transformer T1 primary winding terminals incorrectly connected.	a. Replace fuse F1. If replaced fuse blows, check items 2 and 3 below. b. Replace power indicator lamp DS1. c. Repair or replace power cable. d. Replace Power switch S2. e. Check connections of transformer T1 primary winding; rewire if necessary.
2. Fuse F1 blows immediately when Power switch S2 is operated to ON.	a. Tube V6 shorted. b. Rectifier CR3 defective. c. Short circuit in transformer T1 or in circuit wiring.	a. Replace rectifier tube V6. b. Replace heater rectifier CR3. c. Remove all tubes, and check transformer windings. Replace transformer T1 if defective. Check for short circuit.
3. Fuse F1 blows after Power switch S2 has been operated to ON and tube heaters have warmed up.	Short in power supply circuit.	Check for short circuit at cathodes V6 and V7. Replace defective component.
4. Power indicator lamp lights; voltmeter does not indicate on all ranges.	a. Power supply or voltage regulator circuits defective. b. Rectifier CR3 or circuit component defective. c. Diode CR1 or CR2 defective.	a. Check tubes V6, V9, V7, and V8 in turn. Check high-voltage winding of transformer T1. Replace defective component. b. Check for 12.6 volts dc across output of rectifier CR3. Check resistors R66 and R68. If tubes V1 and V2 are not lighted, check capacitor C39. Replace defective component. c. Replace diode (paragraph 5-15).
5. Meter indication normal on low ranges (.001 to .3 volts). Meter sensitivity distorted on high-voltage ranges (1 to 300 volts).	Compensated 1000:1 divider defective.	Check C4 and R4. Replace defective component.
6. Meter indicates low on all ranges.	a. Low amplifier gain. b. Diode CR1 or CR2 defective.	a. Check B+ voltage (paragraph 5-20). Check tubes V2 through V5 for low emission. If any tube is replaced, check and recalibrate the voltmeter (paragraph 5-22). b. Replace diode (paragraph 5-15).
7. Meter indication unstable or erratic.	a. Power supply, circuit defective. b. Amplifier tube V1, V2, V3, V4, and V5 defective.	a. Check heaters and B+ voltage. Replace defective component. b. Check V1 through V5 for microphonics or noise. If tube is replaced, check and recalibrate the voltmeter (paragraph 5-22).
8. Meter indication normal on .001 and 1 volt range. Meter sensitivity distorted on all other ranges (.003, .01, .03, .1, .3, 3, 10, 30, 100, and 300 volts).	Faulty RANGE switch S1.	Check switch contacts of S1. Replace RANGE switch S1 if defective (paragraph 5-16).

Figure 5-5. Trouble-Shooting Procedure

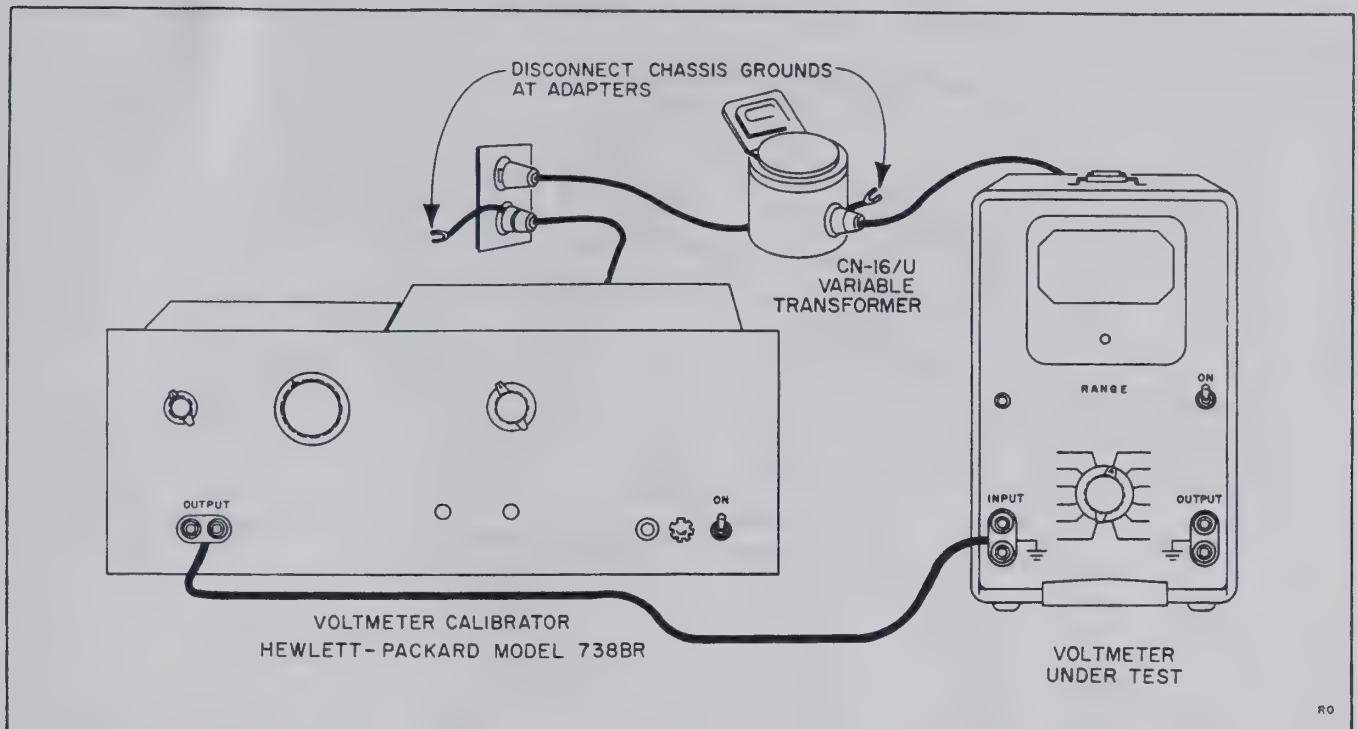


Figure 5-6. Test Setup for Calibration Check and Adjustments

The residual reading on voltmeter must be no higher than the residual reading obtained with voltmeter INPUT terminated with a 10-megohm resistor and shielded to prevent stray pickup. If the residual reading is higher when connected to the calibrator, refer to paragraph 3-12.

e. Set the voltmeter RANGE switch to .001. Set the voltmeter calibrator to provide .001 volt rms (400 cps) output. Record deviation of voltmeter reading from 1 on the voltmeter scale.

f. Set the voltmeter RANGE switch to 1. Set the voltmeter calibrator to provide 1 volt rms output. Record deviation of voltmeter reading from 1 on the voltmeter scale.

g. Still using the voltmeter 1-volt range, reduce the voltmeter calibrator output in 0.1 volt steps. Record deviation of voltmeter readings from each 0.1 volt calibration mark.

h. Compare recorded deviations with the permissible errors listed in the performance specifications in figure 1-2.

i. Connect the voltmeter as shown in figure 5-7 and set line voltage to 115. (This setup measures calibration accuracy at low and high frequencies.)

j. Set voltmeter RANGE switch to .001. Set frequency response test set OUTPUT ATTENUATOR to .001 to measure the lowest voltmeter range; initially set AMPLITUDE control for 0 volts output. Then note volt-

meter reading; it must not be higher than the residual reading noted in step d.

k. Turn the frequency response test set RANGE SELECTOR to EXTERNAL. Set the external oscillator frequency to 400 cps; adjust the oscillator output level to obtain a reading of .9 on the 0 to 1 VOLTS scale of the voltmeter. Then adjust the METER SET control on the frequency response test set to obtain a standard meter indication at the SET LEVEL mark on the test set meter.

l. Tune the external oscillator to 10 cps and adjust its output level to keep the frequency response test set meter reading at SET LEVEL. Do not adjust the METER SET control as this would alter the fixed monitoring point of the meter. Record the voltmeter deviation from .9 on the scale. This reading must be between 0.85 and 0.95 to be within specifications.

m. Set the RANGE SELECTOR on the test set to 3-10 mc, set the FREQ. TUNING dial to 4, and adjust the AMPLITUDE control to keep the frequency response test set meter reading at SET LEVEL. Record the voltmeter deviation from .9 on the scale. This reading must be between 0.85 and 0.95 to be within specifications. The gain and frequency response of the basic voltmeter amplifier is now tested.

n. Repeat step m using line voltages of 103 and 127. Record voltmeter deviation from .9 on the scale.

o. Set voltmeter RANGE switch to .003 and also set the frequency response test set OUTPUT ATTENUATOR to .003 to check this voltmeter range. Repeat steps k and m. Record voltmeter deviation from .9 on the scale.

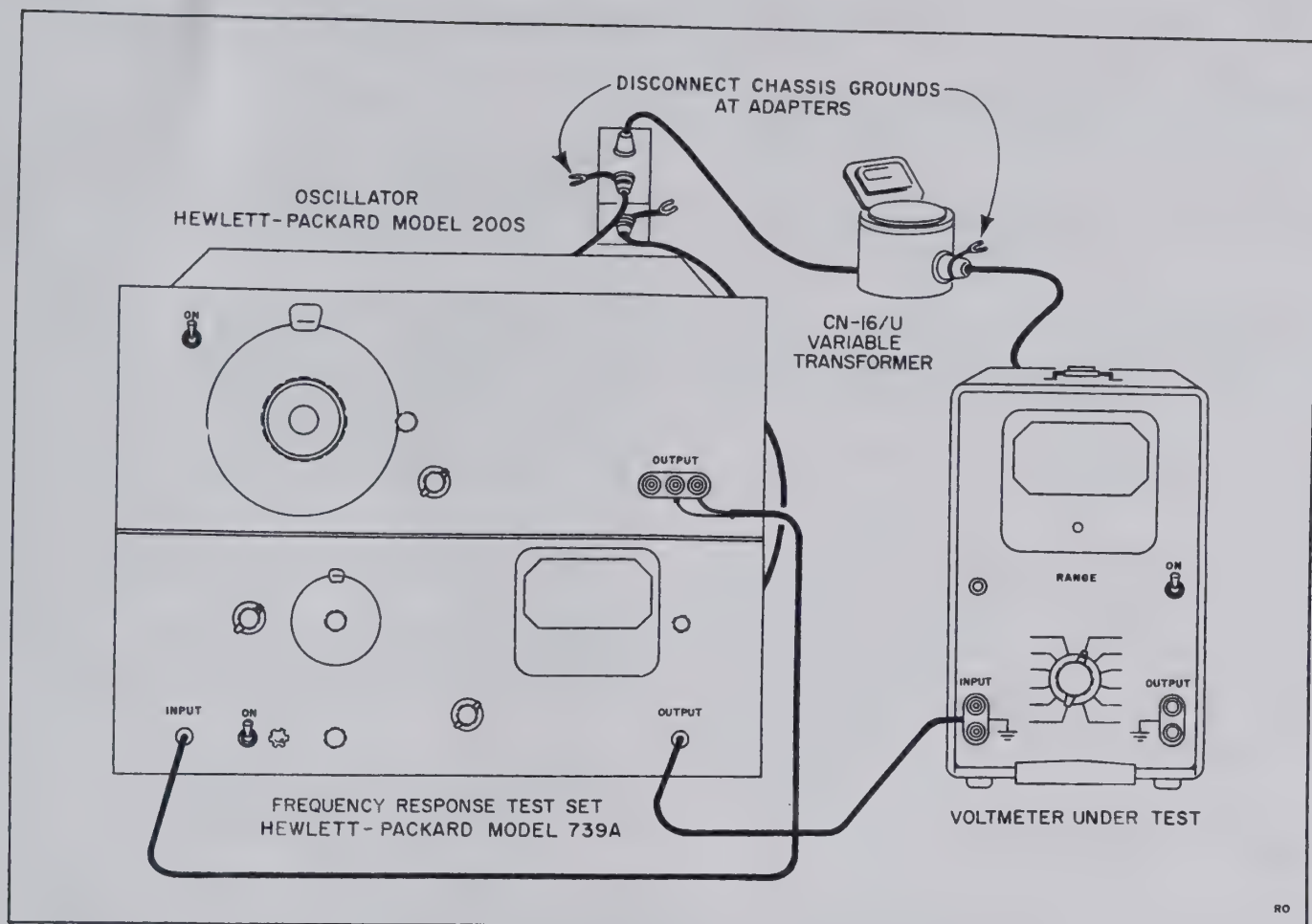


Figure 5-7. Test Setup for Frequency Response Check and Adjustment

p. Set voltmeter RANGE switch to .01 and also set the frequency response test set OUTPUT ATTENUATOR to .01 to check this voltmeter range. Repeat steps k and m. Record voltmeter deviation from .9 on the scale.

q. Set voltmeter RANGE switch to 1 and also set the frequency response test set OUTPUT ATTENUATOR to 1. Repeat step k.

r. Turn the frequency response test set RANGE SELECTOR to EXTERNAL. Set external oscillator frequency to 20 kc and adjust output level to keep the frequency response test set meter reading at SET LEVEL. Record voltmeter deviation from .9 on the scale.

s. Repeat step m and record voltmeter deviation from .9 on the scale.

t. The voltmeter is now completely tested. If the measurements made have shown the voltmeter reading to be within the tolerances given in the performance specifications in Section I, the voltmeter is operating satisfactorily. If operation is unsatisfactory, make calibration and frequency response adjustments as directed in paragraph 5-24.

5-24. CALIBRATION AND FREQUENCY RESPONSE ADJUSTMENTS.

5-25. Calibration and frequency response adjustments may be required when components other than those in the power supply circuit are replaced. After replacing any of these components, carry out the voltmeter performance test of paragraph 5-22 to see if adjustments are necessary. If the voltmeter operates within specifications during the test of paragraph 5-22, with respect to both calibration (at mid-frequencies) and frequency response, no adjustments are needed. If operation at mid-frequencies meets calibration specifications, only the frequency response adjustments need be made. Otherwise, make all calibration and frequency response adjustments in the order listed in the following procedure.

5-26. Calibration of the voltmeter consists of five parts:

- Setting the basic gain of the amplifier at 400 cps.
- Setting the division ratio of the input attenuator at 400 cps.
- Setting the frequency response of the amplifier.
- Setting the 4-mc frequency response of the step attenuator.

e. Setting the 20-kc and 4-mc frequency response of the input divider.

NOTE

It is important to follow the complete procedure in the order given, instead of attempting individual adjustments which might appear to correct a certain fault in calibration.

5-27. Although a special voltmeter calibrator instrument and frequency response test set (listed in paragraph 5-5) are shown for calibrating the voltmeter, other precision a-c voltage sources having the required accuracy may be used for this calibration procedure. In the following procedure, the mechanical meter zero-set and the regulated B+ voltage must already be correctly set (see paragraphs 5-7 and 5-20, respectively). Proceed as follows:

a. Connect voltmeter calibrator and voltmeter under test as shown in figure 5-6. (Do not turn on.)

b. Provide a ground-level input to the voltmeter to check for stray pickup between the instruments by setting the voltmeter calibrator controls as follows:

OUTPUT SELECTOR to 400~RMS
RANGE SELECTOR switch to 1.5 - 5
VOLTAGE SELECTOR switch to 0
POWER switch to ON

c. Set the RANGE switch on the voltmeter under test to .001 volt, and the Power switch to ON. Allow at least a ten-minute warmup. Refer to paragraph 3-12 of this manual and to the manual for the Model 738BR Voltmeter Calibrator for a procedure to test for ground currents. Eliminate any ground currents by breaking ground loops as directed in paragraph 3-12.

d. To test the .001 volt range, set the voltmeter calibrator to .001 volt and the voltmeter RANGE switch to .001. If necessary, adjust R107 (figure 5-3) to obtain a reading of exactly 1 on the 0 to 1 VOLTS scale on the panel meter of the voltmeter under test. This sets the gain of the amplifier at audio frequencies.

e. Set the RANGE switch on the voltmeter to the 1-volt range. Set the voltmeter calibrator to 1 volt, to test this range. If necessary, adjust R101 (figure 5-3) to obtain a reading of exactly 1 volt on the voltmeter. This sets the division ratio of the input voltage divider at audio frequencies.

f. Connect the frequency response test set, the oscillator, and the voltmeter under test as shown in figure 5-7. Observe grounding precautions described in step c.

g. On the frequency response test set, set the OUTPUT ATTENUATOR to .001, the RANGE SELECTOR to EXTERNAL, and turn the Power switch ON. This adjusts the frequency response test set to provide an output from the external oscillator for the voltmeter .001-volt range.

h. Set the RANGE switch on the voltmeter under test to .001.

i. Set the oscillator for 400 cps output frequency and adjust its output level to obtain a reading at 0.9 on the voltmeter scale.

j. Adjust the frequency response test set METER SET control to obtain a meter reading at SET LEVEL on the test set. This standardizes the monitoring point of the output level.

k. Set the RANGE SELECTOR and FREQ. TUNING controls of the frequency response test set for 4-mc output frequency and adjust the AMPLITUDE control to provide a reading at SET LEVEL on the meter.

l. If necessary adjust C102 (figure 5-3) to obtain a reading at 0.9 on the voltmeter under test. This sets amplifier gain at video frequencies.

m. While watching voltmeter under test, adjust the frequency response test set FREQ. TUNING control from 4 to 10 Mc while holding output level constant with AMPLITUDE control. The frequency response curve increases from 4 to approximately 6 Mc and then drops off from approximately 6 to 10 Mc. The frequency response of instrument is within specification if voltmeter reading remains in 0 to 0.92 range. If not in specifications adjust R119 and repeat steps g through l.

NOTE

Whenever R119 is adjusted, both lo- and hi-freq. response is affected and must be retested.

n. Readjust oscillator and frequency response test set for 20 cps output and a SET LEVEL indication on the test set meter. If necessary adjust R118 (figure 5-4) to obtain a reading at exactly 0.9 on the voltmeter under test.

o. Repeat step n at a frequency of 10 cps, for a voltmeter reading between 0.85 and 0.95 ($\pm 5\%$). If 10 cps response is outside this range, readjust R118 slightly to bring 10 cps response within the specified limits.

p. Repeat the 400-cps to 4-mc frequency response check (steps g through k) on the .003 volt range of the voltmeter and if necessary adjust C14 (figure 5-4) to obtain a reading of 0.9 on the voltmeter at 4 mc.

q. Repeat the 400-cps to 4-mc frequency response check (steps g through k) on the 0.01 volt range of the voltmeter and if necessary adjust C16 (figure 5-4) to obtain a reading of 0.9 on the voltmeter at 4 mc.

r. On the 1-volt range of the voltmeter, measure frequency response at both 20 kc and 4 mc using a procedure similar to steps g through k. At 20 kc if necessary adjust C4 (figure 5-3) to obtain a reading of 0.9 on the voltmeter. At 4 mc if necessary pad the value of R6 (figure 5-3) to obtain a reading between 0.85 and 0.95 ($\pm 5\%$). R6 consists of several resistors connected in parallel. Increasing the value of one of these resistors raises the meter reading at 4 mc. The input shield must be in place on the voltmeter chassis when making this reading.

V7 (12B4)
SERIES REGULATOR

+245
54K
+225
400K
+120.6.3 VAC
260K
+232
360K
+216
350K
+120.0VAC
260K

V6 (6AX5)
HIGH VOLTAGE RECTIFIER

+125
240K
+125.6.3 VAC
220K
+450
55K
+390VAC
150

V9 (5651)
REFERENCE TUBE

+87
130K

V4 (6CB6)
3RD AMPLIFIER

+6.3
2.0
+12.6
3.0
+5.2
520
+3.5
100K
+115
75 K
+143
100K

V5 (6CB6)
4TH AMPLIFIER

0.5 VAC
60
+5.6
560
+3.5
890
+136
100K

V3 (6CB6)
2ND AMPLIFIER

+127
110K
+135
70K
+6.3
2.0
+12.6
3.0
+4.9
525
+12.6
3.0

V8 (6U8)
CONTROL TUBE

+125.6.3 VAC
240K
+133
40K
+88
70K
+245
50K
+125.0VAC
260K
+218
420K
+90
18K
+87
200K

V1 (6CB6)
INPUT CATHODE FOLLOWER

+170
70K
+6.3
2.0
+54
10.1M
+58
6600

V2 (6CB6)
1ST AMPLIFIER

+110
130K
+115
90K
+6.3
2.0
+1.4
135

NOTES:

- CONDITIONS OF DC VOLTAGE MEASUREMENTS:
A. BETWEEN INDICATED POINT AND GROUND WITH HP-412A.
B. NO CONNECTION TO INPUT OR OUTPUT.
C. LINE VOLTAGE; 115 VOLTS, 50 CYCLES.
D. DB VOLTS SWITCH, 300V RANGE.
- VOLTAGES MAY VARY UP TO ±10%.
- CONDITIONS OF RESISTANCE MEASUREMENTS:
A. BETWEEN INDICATED POINT AND GROUND WITH MULTIMETER.
B. EXTERNAL CABLES DISCONNECTED.
C. CIRCUIT CAPACITY MUST BE CHARGED BY OHMMETER BEFORE ACCURATE RESISTANCE READING CAN BE OBTAINED.
- RESISTANCE MEASUREMENTS MAY VARY UP TO ±10%.

L.O.E.-178

Figure 5-8. Voltage and Resistance Diagram

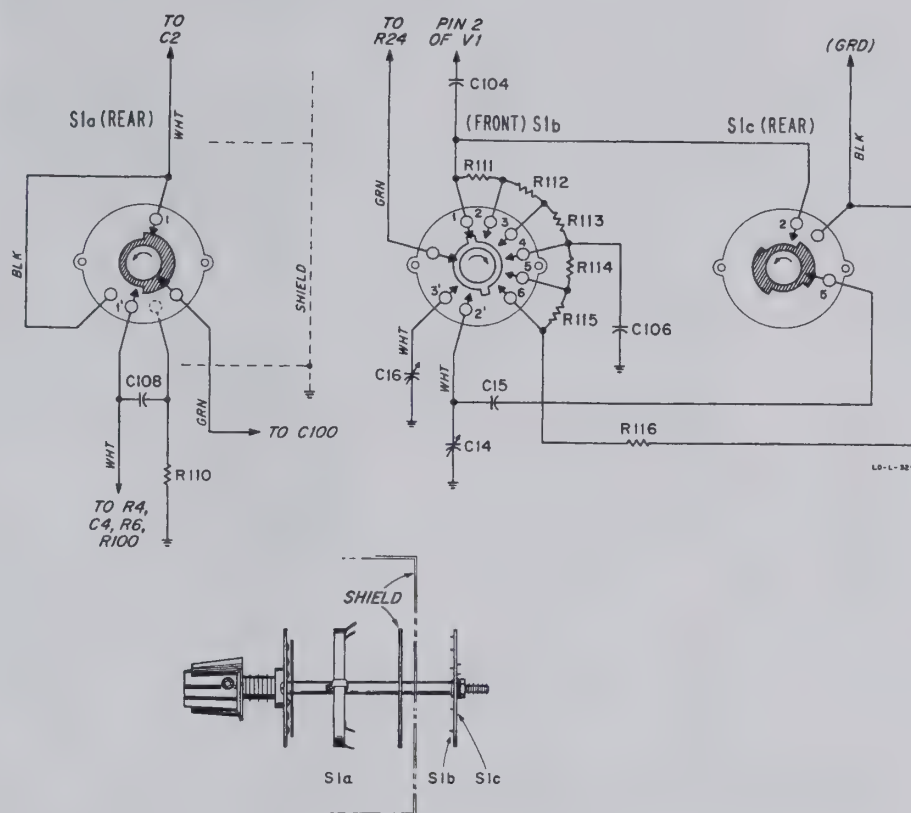


Figure 5-9. Diagram of RANGE Switch

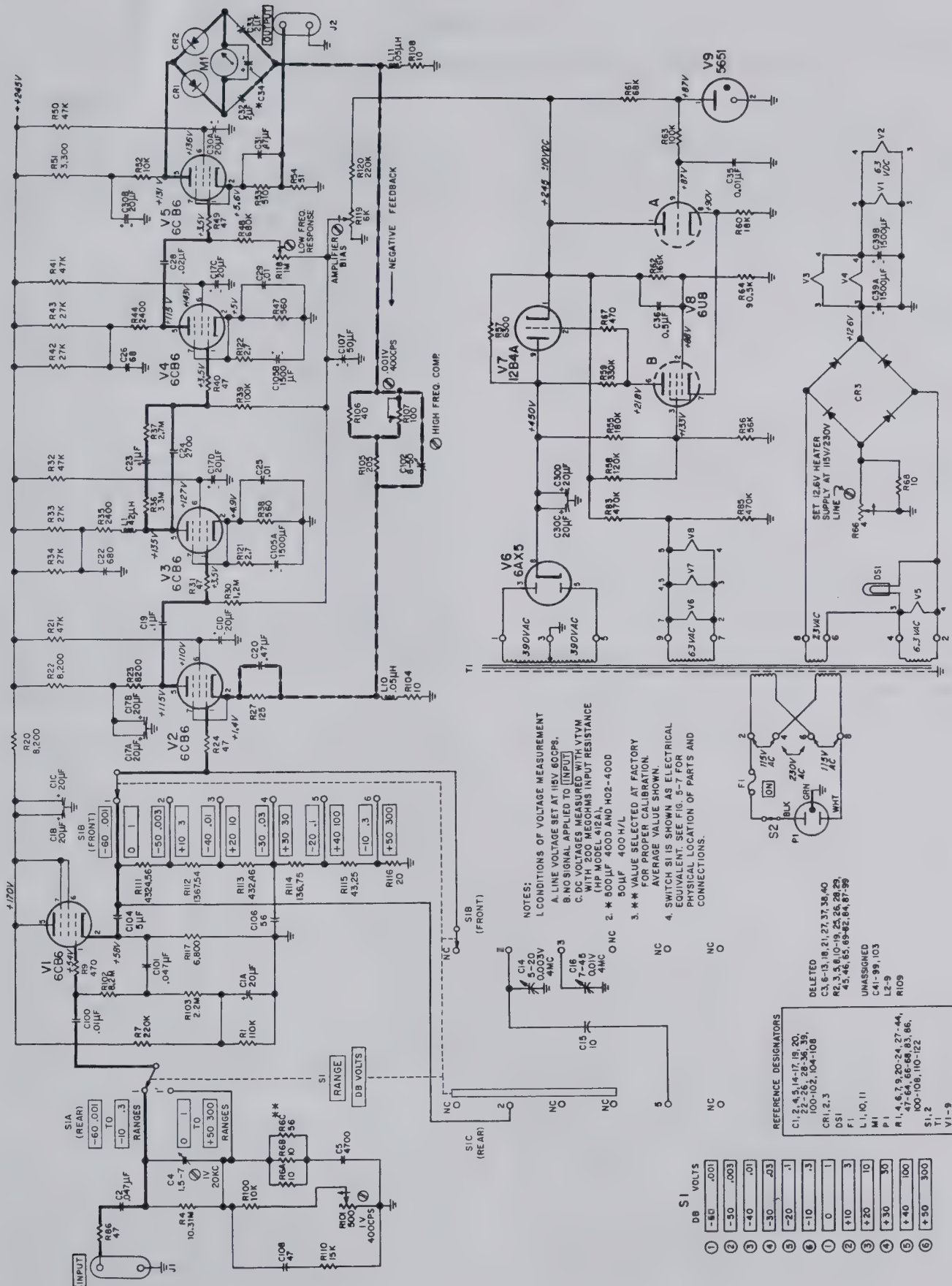


Figure 5-10. Voltmeter Schematic Diagram

SECTION VI

INTRODUCTION TO ILLUSTRATED PARTS BREAK DOWN

6-1. GENERAL.

6-2. This Illustrated Parts Breakdown lists and describes the parts applicable to the Vacuum Tube Voltmeters, Models 400D, 400H, 400L, and H02-400D, manufactured by Hewlett-Packard Co. The breakdown consists of four sections as shown in the Table of Contents.

6-3. GROUP ASSEMBLY PARTS LIST. The Group Assembly Parts List (Section VII) consists of the complete Voltmeter divided into six main assemblies or components as shown in the Table of Contents. Each assembly listed is followed immediately by its component parts indented to show relationship to the assembly.

6-4. Part numbers are used to identify parts. A MIL-type part number or a typical manufacturer and part number are listed for each vendor part in the Group Assembly Parts List. The actual part used may be supplied by a different vendor, but in all cases the Hewlett-Packard stock number remains the same. The H-P Stock No. column is adjacent to the manufacturer or military Part No. column.

6-5. The index numbers are numerically arranged in the Group Assembly Parts List and are used mainly to assist in locating a part in the Group Assembly Parts List after it has been found in the Numerical Indexes (Section VIII) or located on the figure which illustrates that particular assembly.

6-6. The nomenclature of each part in the Group Assembly Parts List is indented to indicate assembly relationship. Each part is indented one column to the right of the next higher assembly. When the details of an assembly are shown on a different figure and parts list, the nomenclature of that assembly is followed by a parenthetical note stating in which figure and parts list the details will be found.

6-7. Attaching parts are shown in the same indent as the parts which they attach, and immediately following the part. They are separated from the parts which they attach by the words (ATTACHING PARTS). The attaching parts are separated from the following assembly, or the details of the assembly which they attach, by the symbol ---*---. When attaching parts are shown as attaching two or more parts, the quantities of the attaching parts are those required to attach the total number of the assemblies or parts being attached.

6-8. The quantities listed in the "Units per Assy" column of the Group Assembly Parts List are, in the case of assemblies, the total quantity used in the Voltmeter at the location indicated. In the case of component parts indented under the assembly, the quantity listed is the quantity used per assembly. The quantities specified in any one entry, therefore, are not necessarily the total used per complete Voltmeter. Refer to the Numerical Indexes (Section VIII) for the total quantities used per complete voltmeter.

6-9. USABLE ON CODE. Part variations within the voltmeters are indicated by a letter symbol or combination of letter symbols in parentheses immediately following the figure and index number in the same column. An explanation of the symbols used is outlined below. In cases where the "Usable on Code" column has been left blank, parts listed apply to all models covered by this book.

USABLE ON CODE	MODEL NUMBER
D	400D
H	400H
L	400L
H02	H02-400D

6-10. PART NO. NUMERICAL INDEX. The Part Number Numerical Index (Section VIII) is compiled in accordance with the numerical part number filing system described below:

a. Part number numerical arrangement starts at the left-hand position of the part number and continues from left to right, one position at a time, until part number numerical arrangement is determined for all the part numbers. In the Part No. Numerical Index the federal stock number consists of a class code prefix followed by a serial number or the part number; that is, when a serial number has been assigned, the class code and serial number form the stock number; when a serial number has not been assigned, the class code and part number form the federal stock number.

b. The order of precedence in the arrangement of the part number is as follows:

- (1) Space (blank position in the number)
- (2) Dash (-)
- (3) Letters A through Z
- (4) Numerals 0 through 9
Alphabetical O's shall be considered as numerical zeros

6-11. In cases where the same part appears in several assemblies and therefore has several different figure and/or index numbers, the Part No. Numerical Index lists the figure and index number of each appearance, and the total quantity of the part used is given on the line with the first figure and index number entry.

6-12. HEWLETT-PACKARD STOCK NO. INDEX. The Hewlett-Packard Stock No. Index is a numerical index of Hewlett-Packard stock numbers, arranged in alphabetical form in the same manner as the Part No. Numerical Index. The Hewlett-Packard Stock No. Index follows the Part No. Numerical Index in Section VIII.

6-13. REFERENCE DESIGNATION INDEX. The Reference Designation Index (Section IX) lists electrical parts by reference designator and is compiled with reference designators in alpha-numerical order. It provides a convenient method for locating parts within the Group Assembly Parts List when the reference designator is known.

6-14. SOURCE CODING. Source coding as applied to the Numerical Indexes has been assigned by Department representatives.

SOURCE CODE DEFINITIONS

a. CODE "P" - PARTS UNDER INVENTORY STOCK CONTROL

(1) CODE "P" is applied to the parts which are procured in view of relatively high usage. Code "P" parts may be requisitioned and installed by any maintenance level, unless followed by the letter - "O", which restricts requisition and replacement to Depot (O&R) level only. Restricted service manufacture is considered practicable but only after an attempt has been made to procure from Supply Sources. In lieu of the procurement of "P" coded parts, the Department may designate a Depot (O&R) level activity to manufacture supply requirements for the Program.

(2) CODE "P1" is applied to parts which are very difficult or uneconomical to manufacture. Service manufacture is considered impracticable. Code "P1" parts may be requisitioned and installed by any maintenance level, unless followed by the letter - "O" which restricts the requisition and replacement to Depot (O&R) level only.

b. CODE "M" MANUFACTURE, PARTS NOT PROCURED

(1) CODE "M" is applied to parts which are within the facilities of any activity to manufacture. Procurement and stocking are not justified in view of the relatively low usage, or storage and installation factors, of these parts. Needs are to be met by local manufacture as required.

(2) CODE "M1" is applied to parts which can be manufactured only by utilizing the facilities of the Depot (O&R) activity. Procurement and stocking of these parts are not justified in view of their relatively low usage and installation factors. The needs of all activities are to be met through salvage, or by Depot (O&R) level manufacture.

c. CODE "A" ASSEMBLE - ASSEMBLY NOT PROCURED

(1) CODE "A" is applied to assemblies made up of two or more units each of which carry individual part numbers and descriptions, and which may be assembled by any maintenance level.

(2) CODE "A1" is applied to assemblies made up of two or more parts each of which carry individual part numbers and descriptions, and which may be assembled only by activities having Depot (O&R) facilities.

d. CODE "X" PARTS CONSIDERED IMPRACTICABLE FOR MANUFACTURE OR PROCUREMENT

(1) CODE "X" is applied to the Main Structural Members or similar parts which, if required, would suggest extensive aircraft or equipment reconditioning. The need of a part, or parts, coded "X" (wing spar caps, center section structure) should normally result in a recommendation to retire the aircraft or equipment from Service.

(2) CODE "X1" is applied to parts for which the procurement of the next larger assembly is justified; e.g., an integral detail part, such as welded segments, inseparable from its assembly; a part machined in a matched set; or a part of an assembly which, if required, would suggest extensive reconditioning of each assembly.

(3) CODE "X2" is applied to parts which are neither procured nor stocked. Activities requiring such parts shall attempt to obtain from salvage; if not obtainable from salvage, such parts shall be requisitioned through normal supply channels with supporting justification.

e. CODE * PARTS NOT PROCURED, MANUFACTURED OR STOCKED

(1) CODE * applies to installation drawings, diagrams, instructions or field service drawings, basic drawing numbers which cannot be procured or manufactured, and obsolete parts.

6-15. VENDOR'S CODE. Vendor's code numbers have been assigned in accordance with Federal Supply Code H-4-1. The vendor's code appears in parentheses following the item name or within the description of each item in the Group Assembly Parts List (Section VII). The vendor's codes used in this Illustrated Parts Breakdown are listed below for convenience.

VENDOR'S CODE

CODE	NAME AND ADDRESS
04009	Arrow, Hart, and Hegeman Electric Co., Hartford, Conn.
14655	Cornell Dubilier Electric Corp., South Plainfield, N.J.
14674	Corning Glass Works, Corning, N.Y.
19701	Electra Mfg. Co., Kansas City, Mo.
24446	General Electric Co., Schenectady, N.Y.

CODE	NAME AND ADDRESS	CODE	NAME AND ADDRESS
28480	Hewlett-Packard Co., Palo Alto, Calif.	83330	Smith, Herman H., Inc., Brooklyn, N.Y.
28520	Heyman Mfg. Co., Kenilworth, N.J.	83380	Buckley, C.E., Leominster, Mass.
35434	Lectrohm, Inc., Chicago, Ill.	84411	Good All Electric Mfg. Co., Ogalala, Nebr.
56289	Sprague Electric Co., North Adams, Mass.	85628	King Engineering Co., Baltimore, Md.
70903	Belden Mfg. Co., Chicago, Ill.	85682	Ringel Bros., Newark, N.J.
71400	Bussman Fuse, Division of McGraw-Edison Co., St. Louis, Mo.	86684	RCA Electron Tube, Division of Radio Corp. of America, Harrison, N.J.
71785	Cinch Mfg. Corp., Chicago, Ill.	88044	Aeronautical Standards Group, Departments of Navy and Air Force, Washington, D.C.
72765	Drake Mfg. Co., Chicago, Ill.	91506	Augat Bros., Inc., Attleboro, Mass.
72982	Erie Resistor Corp., Erie, Pa.	91637	Dale Products, Inc., Columbus, Nebr.
73734	Federal Screw Products Co., Chicago, Ill.	91662	Elco Corp., Philadelphia, Pa.
75915	Littlefuse, Inc., Des Plaines, Ill.	93519	General Electric Co., Lamp Works, Oakland, Calif.
78189	Shakeproof, Division of Illinois Tool Works, Elgin, Ill.	96906	Military Standards
81482	Cooperative Industries, Inc., Chester, N.J.	99849	St. Louis Blow Pipe and Heater Co., Inc., St. Louis, Mo.
82577	Hughes Aircraft Co., Culver City, Calif.		

SECTION VII

GROUP ASSEMBLY PARTS LIST

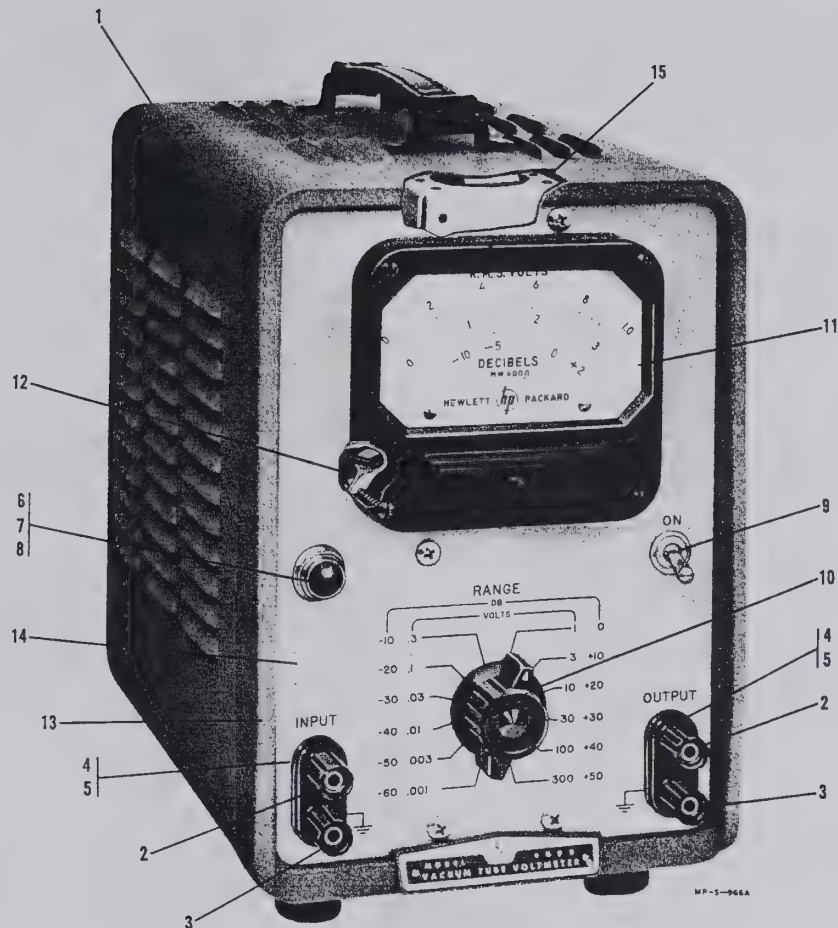


Figure 7-1. 400D/H/L Vacuum Tube Voltmeter

FIG. & INDEX NO.	H-P STOCK NO.	MRF. OR MIL PART NO.	DESCRIPTION							UNITS PER ASSY
			1	2	3	4	5	6	7	
7-1- (D) (H) (L) (H02) -1	400D	400D	VACUUM TUBE VOLTMETER (28480) . . .							1
	400H	400H	VACUUM TUBE VOLTMETER (28480) . . .							1
	400L	400L	VACUUM TUBE VOLTMETER (28480) . . .							1
	H02-400D	H02-400D	VACUUM TUBE VOLTMETER (28480) . . .							1
	400D-44	400D-44	CABINET ASSEMBLY (28480)							1
			(ATTACHING PARTS)							
	2520-0006	AN526-832-10	SCREW, MACHINE							2
			---*---							

Section VII
Group Assembly Parts List

T. O. 33A1-12-349-1

FIG. & INDEX NO.	H-P STOCK NO.	MFR. OR MIL PART NO.	DESCRIPTION							UNITS PER ASSY
			1	2	3	4	5	6	7	
7-1-		NO NUMBER	.						PANEL ASSEMBLY, FRONT	1
									(ATTACHING PARTS)	
	2520-0003	AN526-832-8	.						SCREW, MACHINE	5
	2580-0003	510-081810-01	.						NUT, ASSEMBLED WASHER (78189) . .	1
			.						---*---	
-2	5060-0634	5060-0634	.	.					POST, BINDING, Red (28480)	2
-3	5060-0635	5060-0635	.	.					POST, BINDING, Black (28480) . . .	2
-4	0340-0089	0340-0089	.	.					INSULATOR, STANDOFF (28480) . .	2
-5	0340-0090	0340-0090	.	.					INSULATOR, STANDOFF (28480) . .	2
-6	1450-0020	14L-15	.	.					LENS, INDICATOR LIGHT (72765) . .	1
-7	2140-0012	12	.	.					LAMP, INCANDESCENT, 6-8 VOLT, 2 pin base (93519)	1
-8	1450-0022	2020-AE	.	.					LAMPHOLDER, 2 pin base (72765) .	1
-9	3101-0001	80994-H	.	.					SWITCH, TOGGLE, SPST (04009) . .	1
-10	0370-0035	0370-0035	.	.					KNOB (28480)	1
-11 (D, H02)	1120-0005	1120-0005	.	.					MULTIMETER, REPLACEMENT . .	1
			.	.					(28480)	
(H)	1120-0301	1120-0301	.	.					MULTIMETER, REPLACEMENT . .	1
			.	.					(28480)	
(L)	1120-0098	1120-0098	.	.					MULTIMETER, REPLACEMENT . .	1
			.	.					(28480)	
-12	1400-0015	1550	.	.					CLAMP, LOOP (73734)	1
-13	5020-0137	5020-0137	.	.					BEZEL, INSTRUMENT MOUNTING (28480)	1
									(ATTACHING PARTS)	
	2360-0003	AN515-6-4	.	.					SCREW, MACHINE	6
			.	.					---*---	
-14 (D, H02)	400D-2	400D-2	.	.					PANEL, FRONT (28480)	1
(H, L)	400H-2A	400H-2A	.	.					PANEL, FRONT (28480)	1
-15		NO NUMBER	.						MAIN CHASSIS ASSEMBLY	1
									(See figure 7-2) (28480)	

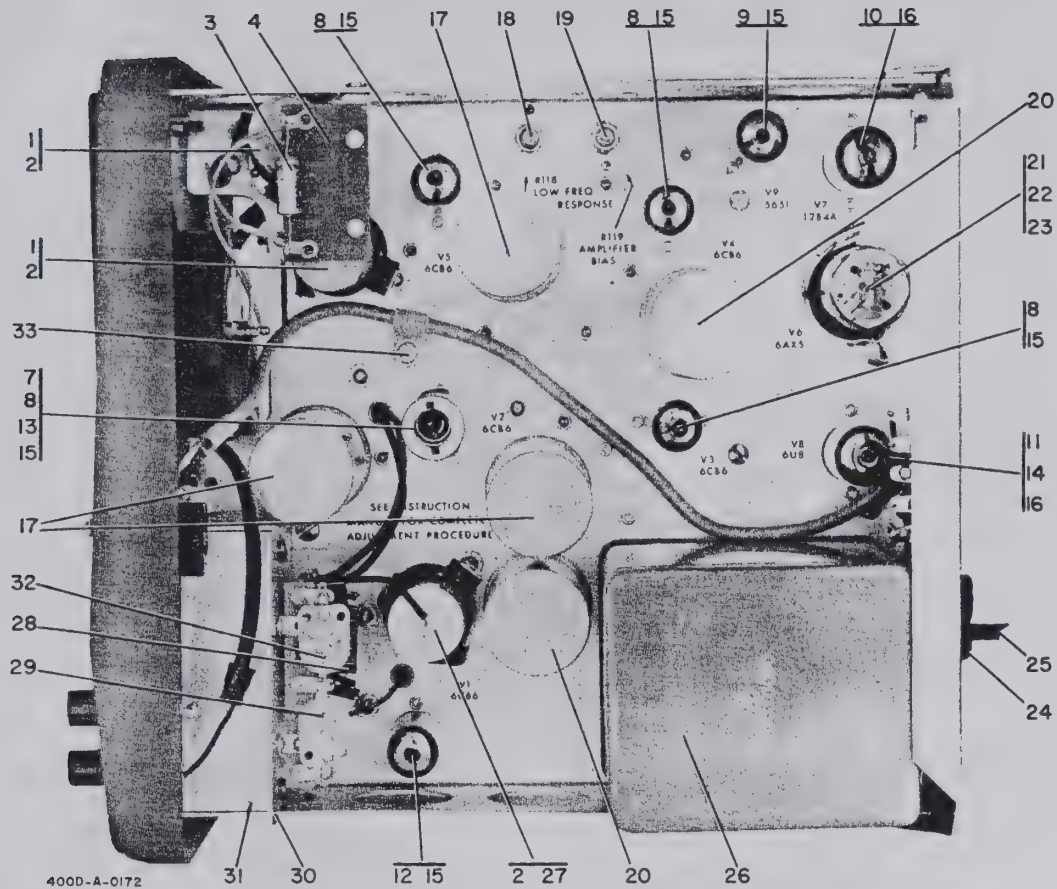


Figure 7-2. Main Chassis Assembly (Sheet 1 of 2)

FIG. & INDEX NO.	H-P STOCK NO.	MFR. OR MIL PART NO.	DESCRIPTION							UNITS PER ASSY
			1	2	3	4	5	6	7	
7-2-		NO NUMBER	MAIN CHASSIS ASSEMBLY (28480)							REF
			(See figure 7-1, index 15 for next higher assembly)							
-1	0170-0002	663UW20504	. CAPACITOR, FIXED, PAPER							2
			. DIELECTRIC, 2.0 μ f \pm 20%, 400 wvdc (84411)							
-2	1390-0020	INSULOID N3	. CLAMP, LOOP (85628)							3
			(ATTACHING PARTS)							
	2420-0001	510-061810-01	. NUT, ASSEMBLED WASHER (78189) . . .							3

-3 (D, H02)	0180-0063	30D120A1	. CAPACITOR, FIXED, ELECTROLYTIC, .							1
			500 μ f +100%, -10%, 3 wvdc (56289)							
(H, L)	0180-0033	30D133A1	. CAPACITOR, FIXED, ELECTROLYTIC, .							1
			50 μ f, 6 wvdc (56289)							
-4	400D-75H	400D-75H	. BRACKET, CAPACITOR (28480)							1
			(ATTACHING PARTS)							
	2390-0009	COML	. SCREW, ASSEMBLED WASHER,							1
			6-32 by 3/8 in. lg, s.s.							

FIG. & INDEX NO.	H-P STOCK NO.	MFR. OR MIL PART NO.	DESCRIPTION							UNITS PER ASSY
			1	2	3	4	5	6	7	
7-2-										
-7	1220-0010	126	.	SHIELD,ELECTRON TUBE (91662) . . .						1
-8	1923-0028	6CB6	.	ELECTRON TUBE (24446)						5
-9	1940-0001	5651	.	ELECTRON TUBE (86684)						1
-10	1921-0010	12B4	.	ELECTRON TUBE (24446)						1
-11	1933-0004	6U8	.	ELECTRON TUBE (24446)						1
-12	5080-0621	6CB6	.	ELECTRON TUBE (24446)						1
-13	1220-0005	429-.125	.	BASE,Tube shield (91662)						1
-15	1200-0009	316PH-3702	.	SOCKET,ELECTRON TUBE (91662) . . .						6
-16	1200-0008	44F-16388	.	SOCKET,ELECTRON TUBE (71785) . . .						2
-17	0180-0025	D32452	.	CAPACITOR,FIXED,ELECTROLYTIC, .						3
				4 section,20 μ f per section,450 wvdc						
				(56289)						
-18	2100-0080	2100-0080	.	RESISTOR,VARIABLE,1M \pm 30%,0.2w . .						1
				(28480)						
-19	2100-0136	2100-0136	.	RESISTOR,VARIABLE,6K \pm 20%,0.3w . .						1
				(28480)						
-20	0180-0028	D27390	.	CAPACITOR,FIXED,ELECTROLYTIC, .						2
				2 section,1500 μ f per section,15 wvdc						
				(56289)						
-21	1930-0014	6AX5-GT	.	ELECTRON TUBE (86684)						1
-22	1400-0033	120D5-63AHS	.	RETAINER,ELECTRON TUBE (91506) .						1
-23	1200-0020	51A12272	.	SOCKET,ELECTRON TUBE (71785) . . .						1
-24	0400-0013	5P-1	.	GROMMET,PLASTIC (28520)						1
-25 (D,H,L)	8120-0050	CS-9941/PH151/ 7.5FT	.	CABLE ASSEMBLY,POWER,						1
				ELECTRICAL (70903)						
(H02)	H02-400D- PWR-CORD	H02-400D-PWR- CORD	.	CABLE ASSEMBLY,POWER,						1
				ELECTRICAL (28480)						
(H02)		CS-9941/PH151/ 7.5FTW/O PLUG	.	CABLE,POWER,ELECTRICAL (70903)						1
(H02)	1251-0037	MS24663	.	CONNECTOR,PLUG,ELECTRICAL						1
				(96906)						
-26	9100-0050	9100-0050	.	TRANSFORMER,POWER,STEP-DOWN						1
				AND STEP-UP (28480)						
				(ATTACHING PARTS)						
	2900-0001	510-101810-51	.	NUT,ASSEMBLED WASHER (78189) . . .						4

-27	0170-0057	S70375	.	CAPACITOR,FIXED,PAPER						1
				DIELECTRIC,5 μ f \pm 10%,100 wvdc (56289)						
-28	0130-0006	503-000-B2P0-28R	.	CAPACITOR,VARIABLE,CERAMIC . .						1
				DIELECTRIC,5-20 pf,500 wvdc (72982) .						
-29	0130-0001	503-000-D2P0-33R	.	CAPACITOR,VARIABLE,CERAMIC . .						1
				DIELECTRIC,7-45 pf,500 wvdc (72982) .						
-30	400D-6J	400D-6J	.	SHIELD,ROTARY SWITCH (28480) . . .						1
				(ATTACHING PARTS)						
	2550-0007	COML	.	SCREW,ASSEMBLED WASHER,8-32 by						2
				3/8 in. lg,s.s.						

-31	400D-6K	400D-6K	.	BRACKET,ANGLE (28480)						1
				(ATTACHING PARTS)						
	2390-0009	COML	.	SCREW,ASSEMBLED WASHER,6-32 by						2
				3/8 in. lg,s.s.						

-32	400D-19A	400D-19A	.	RANGE SWITCH ASSEMBLY (28480) . .						1
				(See figure 7-3)						

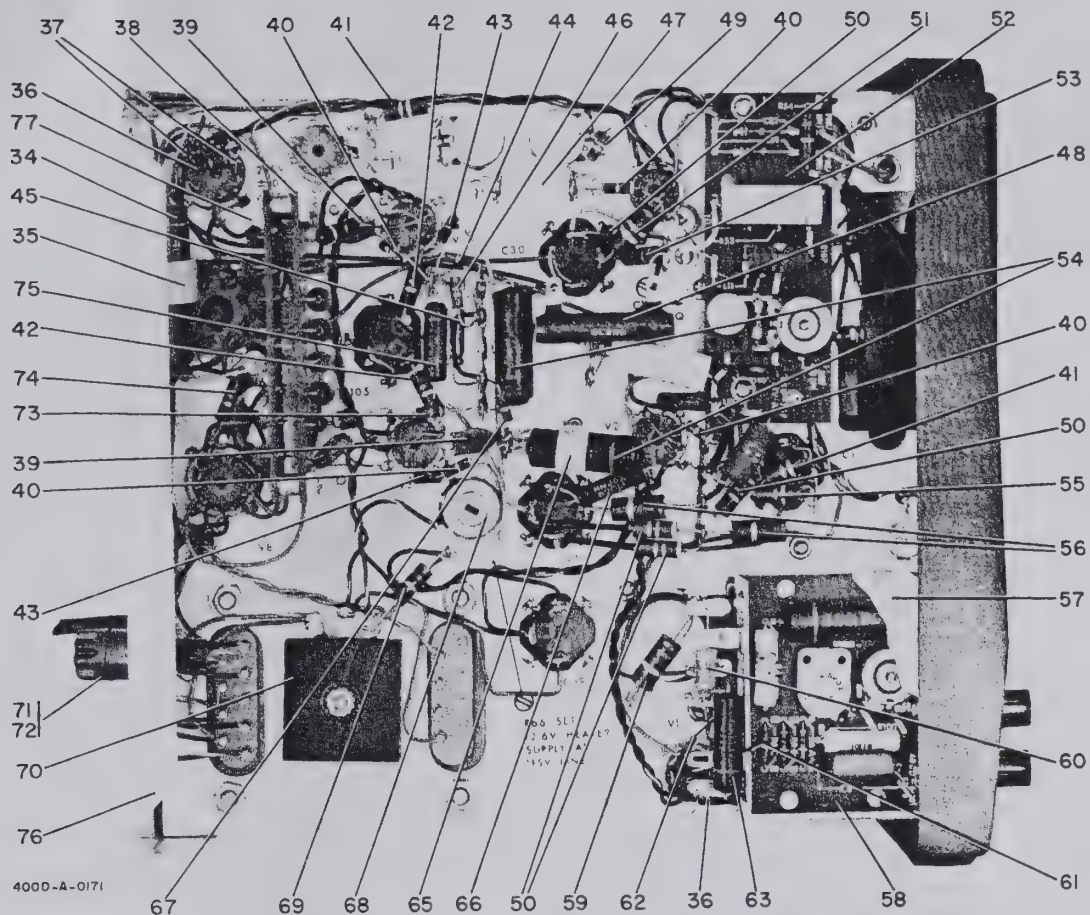


Figure 7-2. Main Chassis Assembly (Sheet 2 of 2)

FIG. & INDEX NO.	H-P STOCK NO.	MFR. OR MIL PART NO.	DESCRIPTION							UNITS PER ASSY
			1	2	3	4	5	6	7	
7-2-33	1400-0074	INSULOID C3	.	CLAMP, LOOP (85682)						1
				(ATTACHING PARTS)						
	2390-0009	COML	.	SCREW, ASSEMBLED WASHER, 6-32 by						1
	3050-0100	AN960-6	.	3/8 in. lg, s.s.						
	2420-0001	510-061810-01	.	WASHER, FLAT (88044)						1
			.	NUT, ASSEMBLED WASHER (78189) . . .						1
			.	-----						
-34	0160-0024	PKM 4P5	.	CAPACITOR, FIXED, PAPER						1
			.	DIELECTRIC, 0.5 μ f \pm 10%, 400 wvdc (14655)						
-35	1400-0016	781	.	CLAMP, LOOP (83330)						1
				(ATTACHING PARTS)						
	2390-0001	COML	.	SCREW, ASSEMBLED WASHER, 6-32 by						1
	2420-0001	510-061810-01	.	1/2 in. lg, s.s. (78189)						
			.	NUT, ASSEMBLED WASHER (78189) . .						1
			.	-----						
-36	0687-4711	RC20GF471K	.	RESISTOR, FIXED, COMPOSITION, . .						2
			.	470 ohm \pm 10%, 1/2w (MIL-R-11)						
-37	0687-4741	RC20GF474K	.	RESISTOR, FIXED, COMPOSITION, . .						2
			.	470K \pm 10%, 1/2w (MIL-R-11)						

FIG. & INDEX NO.	H-P STOCK NO.	MFR. OR MIL PART NO.	DESCRIPTION							UNITS PER ASSY
			1	2	3	4	5	6	7	
7-2-38	400D-75G	400D-75G	.	PRINTED CIRCUIT BOARD ASSEMBLY (28480) (See figure 7-4)						1
				(ATTACHING PARTS)						
	2390-0009	COML	.	SCREW, ASSEMBLED WASHER, 6-32 by 3/8 in. lg, s.s. ---*---						2
-39	0150-0012	29C214A3-H-1038	.	CAPACITOR, FIXED, CERAMIC DIELECTRIC, 0.01 μ f \pm 20%, 1000 wvdc (56289)						3
-40	0687-4701	RC20GF470K	.	RESISTOR, FIXED, COMPOSITION, . . . 47 ohm \pm 10%, 1/2w (MIL-R-11)						4
-41	0690-2241	RC32GF224K	.	RESISTOR, FIXED, COMPOSITION, . . . 220K \pm 10%, 1w (MIL-R-11)						2
-42	0699-0005	RC32GF2R7K	.	RESISTOR, FIXED, COMPOSITION, . . . 2.7 ohm \pm 10%, 1w (MIL-R-11)						2
-43	0687-5611	RC20GF561K	.	RESISTOR, FIXED, COMPOSITION, . . . 560 ohm \pm 10%, 1/2w (MIL-R-11)						2
-44	0687-2751	RC20GF275K	.	RESISTOR, FIXED, COMPOSITION, . . . 2.7M \pm 10%, 1/2w (MIL-R-11)						1
-45	0180-0033	30D133A1	.	CAPACITOR, FIXED, ELECTROLYTIC, 50 μ f, 6 wvdc (56289)						1
-46	0687-1041	RC20GF104K	.	RESISTOR, FIXED, COMPOSITION, . . . 100K \pm 10%, 1/2w (MIL-R-11)						1
-47	0170-0063	143P22394	.	CAPACITOR, FIXED, PLASTIC . . . DIELECTRIC, 0.020 μ f \pm 10%, 400 wvdc (56289)						1
-48	0816-0017	C-10-6.3K	.	RESISTOR, FIXED, WIRE WOUND, . . 6.3K \pm 10%, 10w (35434)						1
-49	0687-6841	RC20GF684K	.	RESISTOR, FIXED, COMPOSITION, . . 680K \pm 10%, 1/2w (MIL-R-11)						1
-50	0690-4731	RC32GF473K	.	RESISTOR, FIXED, COMPOSITION, . . 47K \pm 10%, 1w (MIL-R-11)						4
-51	0693-1031	RC42GF103K	.	RESISTOR, FIXED, COMPOSITION, . . 10K \pm 10%, 2w (MIL-R-11)						1
-52	400D-75F	400D-75F	.	PRINTED CIRCUIT BOARD ASSEMBLY (28480) (See figure 7-5)						1
				(ATTACHING PARTS)						
	2360-0012	AN526-632-14	.	SCREW, MACHINE (88044)						2
	2190-0006	AN935-6	.	WASHER, LOCK (88044)						2
	0380-0008	2102	.	SPACER, SLEEVE (83330)						2
	2420-0001	510-061810-01	.	NUT, ASSEMBLED WASHER (78189) . . ---*---						2
-53	0690-3321	RC32GF332K	.	RESISTOR, FIXED, COMPOSITION, . . 3.3K \pm 10%, 1w (MIL-R-11)						1
-54	0160-0013	160P10494	.	CAPACITOR, FIXED, PAPER DIELECTRIC, 0.1 μ f \pm 10%, 400 wvdc (56289)						2
-55	0689-1145	RC32GF114J	.	RESISTOR, FIXED, COMPOSITION, . . 110K \pm 5%, 1w (MIL-R-11)						1
-56	0693-8221	RC42GF822K	.	RESISTOR, FIXED, COMPOSITION, . . 8.2K \pm 10%, 2w (MIL-R-11)						2
-57	400D-6H	400D-6H	.	SHIELD, Input printed circuit board . . assembly (28480)						1
				(ATTACHING PARTS)						
	2420-0001	510-061810-01	.	NUT, ASSEMBLED WASHER (78189) . . ---*---						2

FIG. & INDEX NO.	H-P STOCK NO.	MFR. OR MIL PART NO.	DESCRIPTION							UNITS PER ASSY
			1	2	3	4	5	6	7	
7-2-58	400D-65C	400D-65C	.	PRINTED CIRCUIT BOARD ASSEMBLY (28480) (See figure 7-6)						1
			.	(ATTACHING PARTS)						
	2390-0009	COML	.	SCREW, ASSEMBLED WASHER, 6-32 by 3/8 in. lg, s.s. ---*---						2
-59	0693-6821	RC42GF682K	.	RESISTOR, FIXED, COMPOSITION, . . . 6.8K $\pm 10\%$, 2w (MIL-R-11)						1
-60	0170-0040	148P47392	.	CAPACITOR, FIXED, PLASTIC DIELECTRIC, 0.047 μ f $\pm 10\%$, 200 wvdc (56289)						1
-61	0687-2251	RC20GF225K	.	RESISTOR, FIXED, COMPOSITION, . . . 2.2M $\pm 10\%$, 1/2w (MIL-R-11)						1
-62	0687-8251	RC20GF825K	.	RESISTOR, FIXED, COMPOSITION, . . . 8.2M $\pm 10\%$, 1/2w (MIL-R-11)						1
-63	0160-0002	160P10396	.	CAPACITOR, FIXED, PAPER DIELECTRIC, 0.01 μ f $\pm 10\%$, 600 wvdc (56289)						1
-64	400D-6F	400D-6F	.	MOUNTING PLATE, Shield (56289) . . .						1
			.	(ATTACHING PARTS)						
	2420-0001	510-061810-01	.	NUT, ASSEMBLED WASHER (78189) . .						2
			.	---*---						
-65	1400-0025	777	.	CLAMP, LOOP (83380)						1
			.	(ATTACHING PARTS)						
	2420-0001	510-061810-01	.	NUT, ASSEMBLED WASHER (78189) . .						2
			.	---*---						
-66	0761-0001	N25-8.2K	.	RESISTOR, FIXED, FILM, 8.2K $\pm 5\%$, 1w .						1
			.	(14674)						
-67	0687-1251	RC20GF125K	.	RESISTOR, FIXED, COMPOSITION, . . . 1.2M $\pm 10\%$, 1/2w (MIL-R-11)						1
-68	2100-0077	2100-0077	.	RESISTOR, VARIABLE, 4 ohm $\pm 20\%$, 1w .						1
			.	(28480)						
-69	0690-1001	RC32GF100K	.	RESISTOR, FIXED, COMPOSITION, . . . 10 ohm $\pm 10\%$, 1w (MIL-R-11)						1
-70	1882-0005	61-6911	.	RECTIFIER, METALLIC (81482) . . .						1
			.	(ATTACHING PARTS)						
	2370-0009	MS35239-42	.	SCREW, MACHINE (96906)						1
	2420-0001	510-061810-01	.	NUT, ASSEMBLED WASHER (78189) . .						1
			.	---*---						
-71	2110-0007	MDL-1	.	FUSE, CARTRIDGE, 1 amp, 250v, slow .						1
			.	blow for 115v (71400)						
-72	1400-0084	3420 14	.	FUSEHOLDER (75915)						1
-73	0687-3351	RC20GF335K	.	RESISTOR, FIXED, COMPOSITION, 3.3M $\pm 10\%$, 1/2w (MIL-R-11)						1
-74	0690-1831	RC32GF183K	.	RESISTOR, FIXED, COMPOSITION, . . . 18K $\pm 10\%$, 1w (MIL-R-11)						1
-75	0160-0044	160P27296	.	CAPACITOR, FIXED, PAPER						1
			.	DIELECTRIC, 0.0027 μ f $\pm 10\%$, 600 wvdc (56289)						
-76	400D-1A	400D-1A	.	PANEL, Rear (28480)						1
-77	400D-1B	400D-1B	.	CHASSIS, ELECTRICAL EQUIPMENT .						1
			.	(28480)						

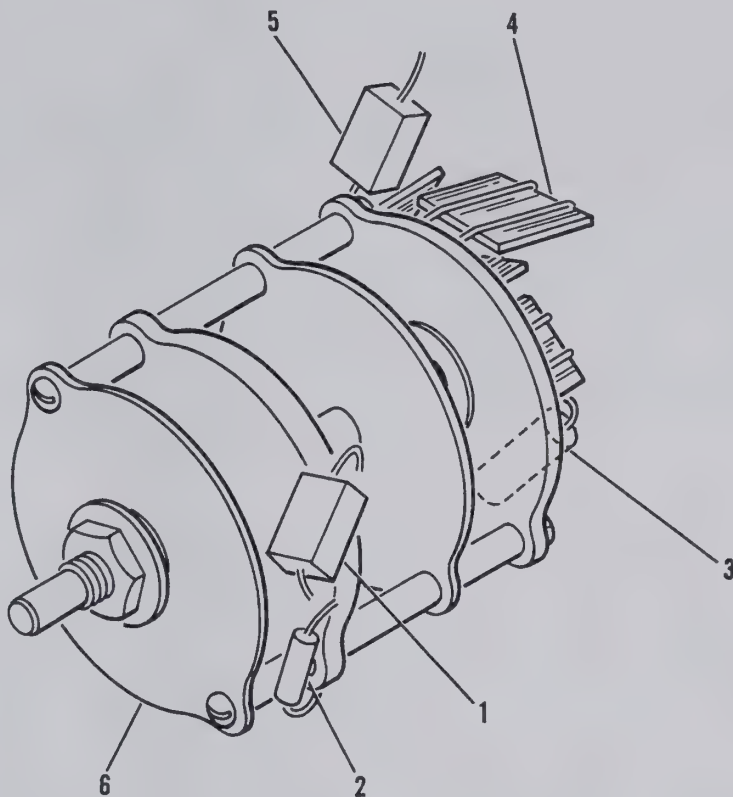


Figure 7-3. Range Switch Assembly

FIG. & INDEX NO.	H-P STOCK NO.	MFR. OR MIL PART NO.	DESCRIPTION							UNITS PER ASSY
			1	2	3	4	5	6	7	
7-3-	400D-19A	400D-19A	RANGE SWITCH ASSEMBLY (28480) (See figure 7-2, index 32 for next higher assembly)							REF
-1	0140-0039	CM15E470J	.							1
-2	0687-1531	RC20GF153K	.							1
-3	0150-0009	315-000-C0G0-100D	.							1
-4	400D-26G	400D-26G	.							1
-5	0140-0014	CM15E560J	.							1
-6	3100-0251	3100-0251	.							1

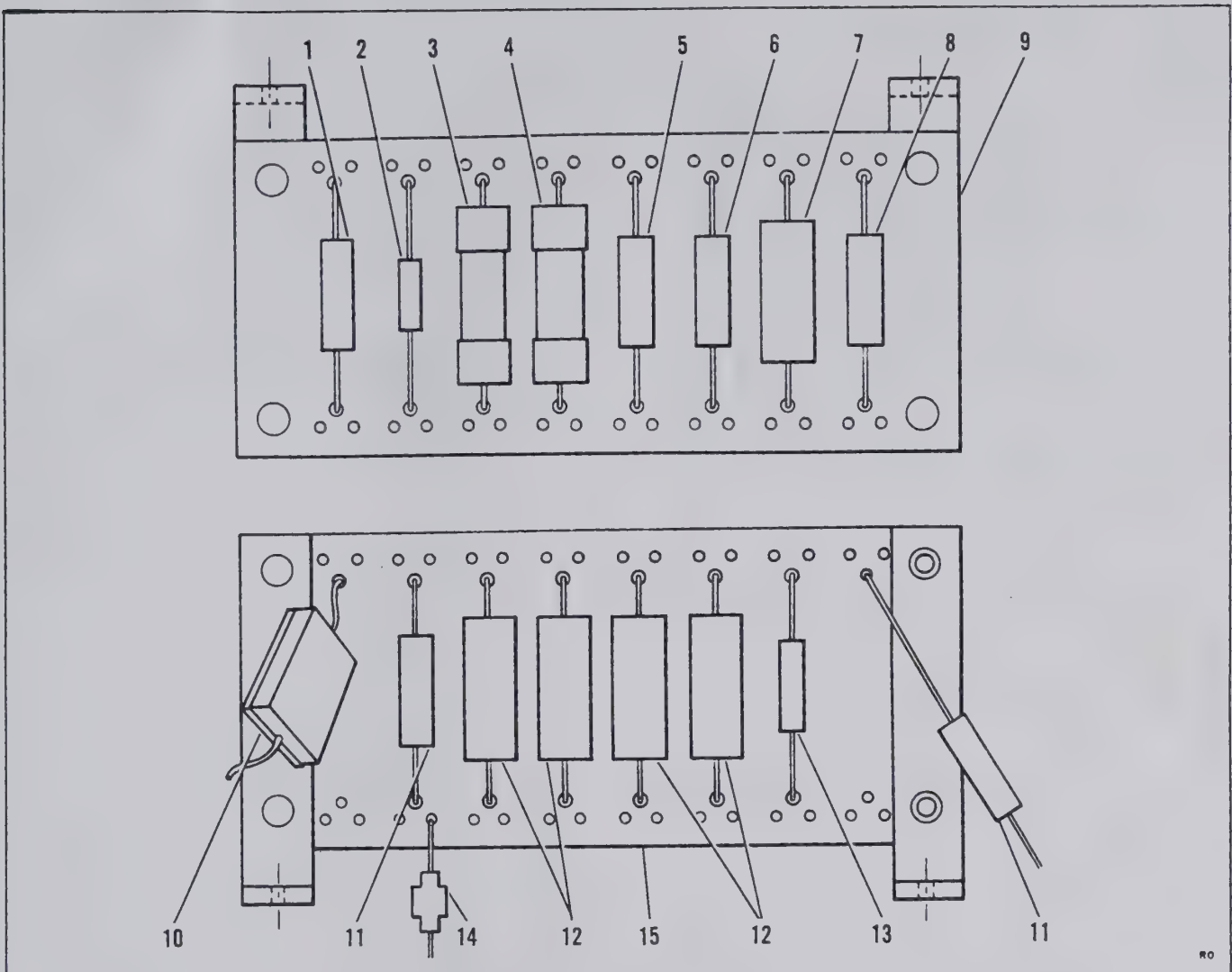


Figure 7-4. Printed Circuit Board Assembly, Part No. 400D-75G

FIG. & INDEX NO.	H-P STOCK NO.	MFR. OR MIL PART NO.	DESCRIPTION							UNITS PER ASSY
			1	2	3	4	5	6	7	
7-4-	400D-75G	400D-75G	PRINTED CIRCUIT BOARD ASSEMBLY . . (28480) (See figure 7-2, index 38 for next higher assembly)							REF
-1	0690-6831	RC32GF683K	. RESISTOR, FIXED, COMPOSITION, . . . 68K $\pm 10\%$, 1w (MIL-R-11)							1
-2	0687-1041	RC20GF104K	. RESISTOR, FIXED, COMPOSITION, . . . 100K $\pm 10\%$, 1/2w (MIL-R-11)							1
-3	0730-0065	DC-1-90.5K	. RESISTOR, FIXED, FILM, 90.5K $\pm 1\%$, 1w . (19701)							1
-4	0730-0076	DC-1-166K	. RESISTOR, FIXED, FILM, 166K $\pm 1\%$, 1w . (19701)							1
-5	0690-1241	RC32GF124K	. RESISTOR, FIXED, COMPOSITION, . . 120K $\pm 10\%$, 1w (MIL-R-11)							1
-6	0690-5631	RC32GF563K	. RESISTOR, FIXED, COMPOSITION, . . 56K $\pm 10\%$, 1w (MIL-R-11)							1
-7	0693-1841	RC42GF184K	. RESISTOR, FIXED, COMPOSITION, . . 180K $\pm 10\%$, 2w (MIL-R-11)							1

FIG. & INDEX NO.	H-P STOCK NO.	MFR. OR MIL PART NO.	DESCRIPTION							UNITS PER ASSY
			1	2	3	4	5	6	7	
7-4-8	0690-3341	RC32GF334K	.	RESISTOR, FIXED, COMPOSITION, . . .						1
-9	400D-75G-2	400D-75G-2	.	330K $\pm 10\%$, 1w (MIL-R-11)						1
-10	0140-0007	CM20B681K	.	PRINTED CIRCUIT BOARD (28480) . . .						1
-11	0689-2425	RC32GF242J	.	CAPACITOR, FIXED, MICA DIELECTRIC, . . .						1
-12	0693-2731	RC42GF273K	.	680 pf $\pm 10\%$, 500 wvdc (MIL-C-5)						2
-13	0140-0025	CM15E680K	.	RESISTOR, FIXED, COMPOSITION, . . .						4
-14	9140-0040	42 μ H-10%- PHENOLIC FORM	.	2.4K $\pm 5\%$, 1w (MIL-R-11)						1
-15	400D-75G-1	400D-75G-1	.	RESISTOR, FIXED, COMPOSITION, . . .						1
			.	27K $\pm 10\%$, 2w (MIL-R-11)						1
			.	CAPACITOR, FIXED, MICA DIELECTRIC, . . .						1
			.	68 pf $\pm 10\%$, 500 wvdc (MIL-C-5)						1
			.	COIL, RF, 42 μ h $\pm 10\%$ (99849)						1
			.	PRINTED CIRCUIT BOARD (28480) . . .						1

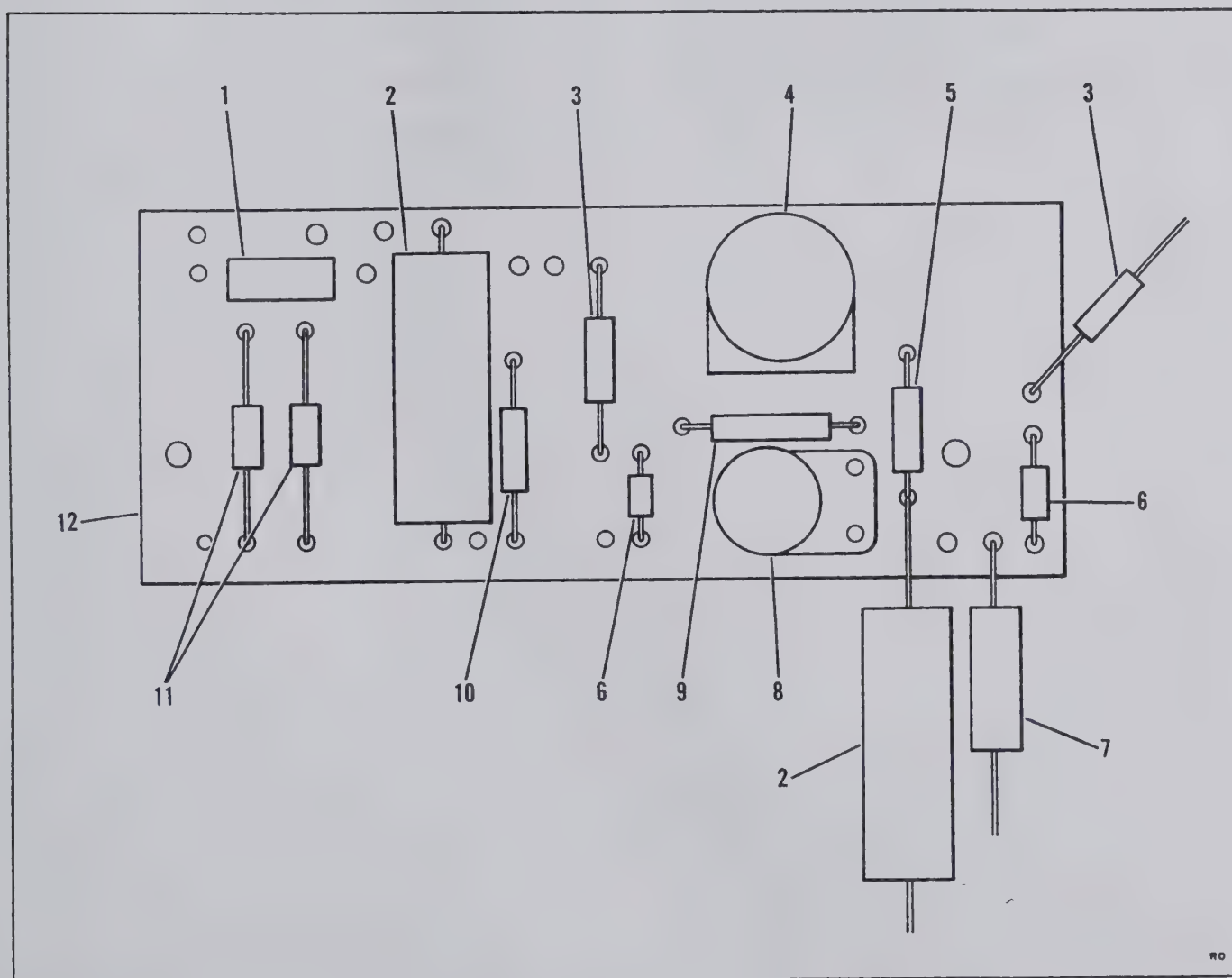


Figure 7-5. Printed Circuit Board Assembly, Part No. 400D-75F

FIG. & INDEX NO.	H-P STOCK NO.	MFR. OR MIL PART NO.	DESCRIPTION							UNITS PER ASSY
			1	2	3	4	5	6	7	
7-5-	400D-75F	400D-75F	PRINTED CIRCUIT BOARD ASSEMBLY . . . (28480) (See figure 7-2, index 52 for next higher assembly)							REF
-1	0689-5105	RC32GF510J	. RESISTOR, FIXED, COMPOSITION, . . . 51 ohm $\pm 5\%$, 1w (MIL-R-11)							1
-2	0170-0064	148P47491	. CAPACITOR, FIXED, PAPER DIELECTRIC, 0.47 μf $\pm 10\%$, 100 wvdc (56289)							2
-3	400D-26F	400D-26F	. RESISTOR, FIXED, WIRE WOUND, . . . 10 ohm $\pm 0.5\%$, 1/2w (28480)							2
-4	2100-0108	2100-0108	. RESISTOR, VARIABLE, 100 ohm $\pm 30\%$, 1/3w (28480)							1
-5	400D-26C	400D-26C	. RESISTOR, FIXED, WIRE WOUND, . . . 205 ohm $\pm 0.5\%$ (28480)							1
-6	400D-60A	400D-60A	. COIL, RADIO FREQUENCY, 0.05 μh (28480)							2
-7	0813-0009	CS-2-125	. RESISTOR, FIXED, COMPOSITION, . . . 125 ohm $\pm 10\%$, 2w (91637)							1
-8	0130-0002	557-000-U2P0-34R	. CAPACITOR, VARIABLE, CERAMIC . . . DIELECTRIC, 8-50 pf, 350 wvdc (72982)							1
-9	0727-0018	DC-1/2C-40	. RESISTOR, FIXED, FILM, 40 ohm $\pm 1\%$, 1/2w (19701)							1
-10	0686-5115	RC20GF511J	. RESISTOR, FIXED, COMPOSITION, . . . 510 ohm $\pm 5\%$, 1/2w (MIL-R-11)							1
-11	1901-0027	HD-5004	. SEMICONDUCTOR DEVICE, DIODE (82577)							2
-12	400D-75F-1	400D-75F-1	. PRINTED CIRCUIT BOARD (28480) . .							1

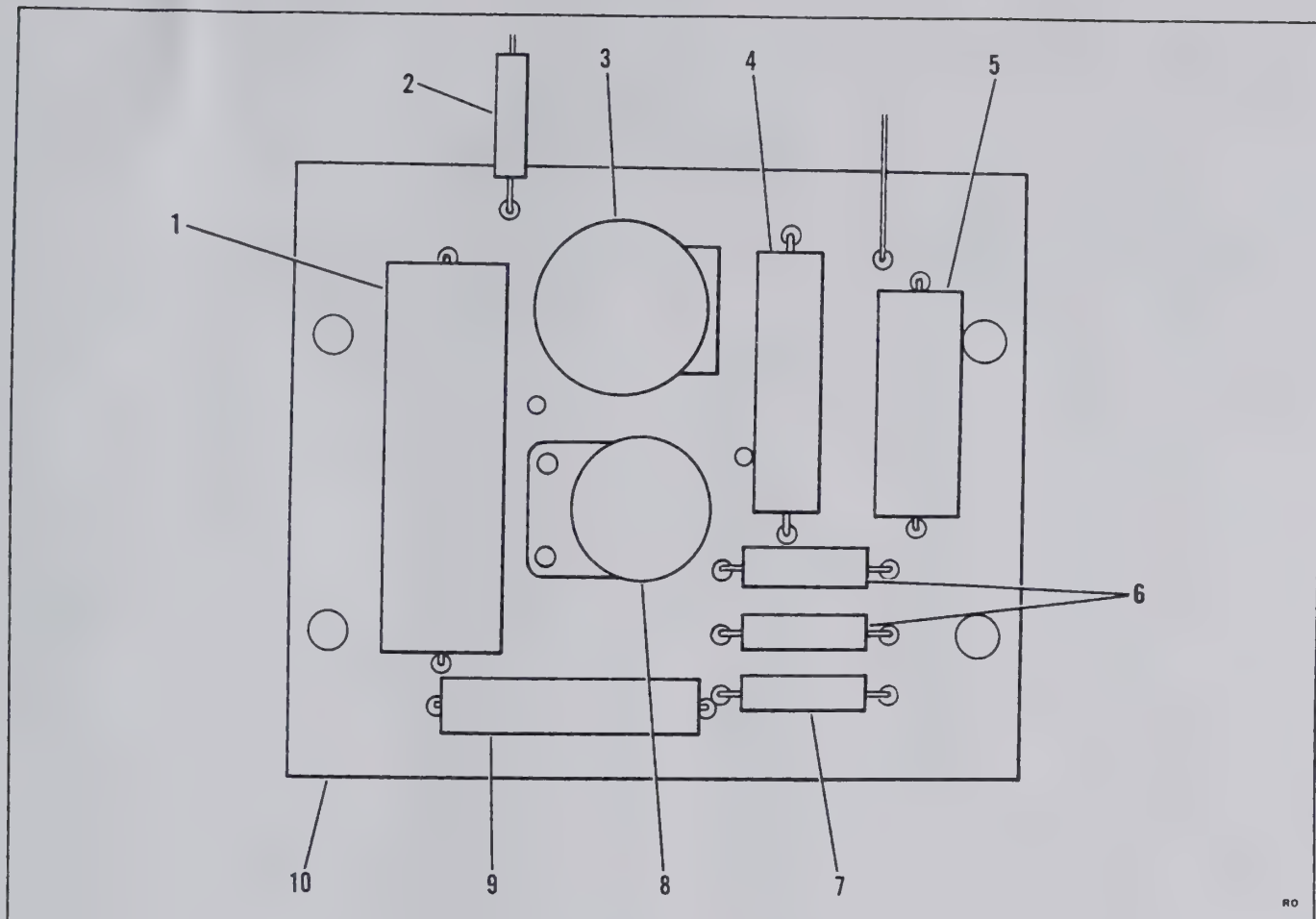


Figure 7-6. Printed Circuit Board Assembly, Part No. 400D-65C

FIG. & INDEX NO.	H-P STOCK NO.	MFR. OR MIL PART NO.	DESCRIPTION							UNITS PER ASSY
			1	2	3	4	5	6	7	
7-6-	400D-65C	400D-65C	PRINTED CIRCUIT BOARD ASSEMBLY . . (28480) (See figure 7-2, index 58 for next higher assembly)							REF
-1	0160-0005	160P47396	. CAPACITOR, FIXED, PAPER DIELECTRIC, 0.047 μ f \pm 10%, 600 wvdc (56289)							1
-2	0687-4701	RC20GF470K	. RESISTOR, FIXED, COMPOSITION, . . . 47 ohm \pm 10%, 1/2w (MIL-R-11)							1
-3	2100-0151	2100-0151	. RESISTOR, VARIABLE, 500 ohm \pm 20%, 1/5w (28480)							1
-4	0730-0029	DC-1-10K	. RESISTOR, FIXED, FILM, 10K \pm 1%, 1w . (19701)							1
-5	0140-0084	CM35E472J	. CAPACITOR, FIXED, MICA DIELECTRIC, 4700 pf \pm 5%, 500 wvdc (MIL-C-5)							1
-6	0687-1001	RC20GF100K	. RESISTOR, FIXED, COMPOSITION, . . 10 ohm \pm 10%, 1/2w (MIL-R-11)							2
-7	0687-5601	RC20GF560K	. RESISTOR, FIXED, COMPOSITION, . . 56 ohm \pm 10%, 1/2w, value selected at factory, optimum value show (MIL-R-11)							1
-8	0130-0003	503-000-C0P0-10R	. CAPACITOR, VARIABLE, CERAMIC DIELECTRIC, 1.5-7 pf, 500 wvdc (72982)							1
-9	0730-0143	DC-1-10.31M	. RESISTOR, FIXED, FILM, 10.31M \pm 1%, 1w (19701)							1
-10	400D-65C-1	400D-65C-1	. PRINTED CIRCUIT BOARD (28480) . .							1

SECTION VIII

NUMERICAL INDEXES

PART NO. NUMERICAL INDEX

MFR. OR MIL. PART NO.	STOCK NO.		FIG. AND INDEX NO.	QTY PER ART.	SOURCE CODE
	CLASS CODE	SERIAL OR PART NO.			
1120-0098	6625		7-1-11	1	
1120-0301	6625		7-1-11	1	
12	6240		7-1-7	1	
12B4A	5960		7-2-10	1	
120D5-63AHS	5960		7-2-22	1	
126	5960		7-2-7	1	
14L-15	6210		7-1-6	1	
148P22394	5910		7-2-47	1	
148P47392	5910		7-2-60	1	
148P47491	5910		7-5-2	2	
1550	5340		7-1-12	1	
160P10396	5910		7-2-63	1	
160P10494	5910		7-2-54	2	
160P27296	5910		7-2-75	1	
160P47396	5910		7-6-1	1	
2020-AE	6250		7-1-8	1	
2100-0077	5905		7-2-68	1	
2100-0080	5905		7-2-18	1	
2100-0108	5905		7-5-4	1	
2100-0136	5905		7-2-19	1	
2100-0151	5905		7-6-3	1	
2102	5340		7-2-	2	
29C214A3-H-1038	5910		7-2-39	3	
30D120A1	5910		7-2-3	1	
30D133A1	5910		7-2-3	2	
			7-2-45		
3100-0251	5930		7-3-6	1	
315-000-C0G0-100D	5910		7-3-3	1	
316PH-3702	5935		7-2-15	6	
342014	5920		7-2-72	1	
400D	6625-643-1670		7-1-	1	
400D-1A			7-2-76	1	
400D-1B	5999		7-2-77	1	
400D-19A			7-2-32	1	
400D-2			7-1-14	1	
400D-26C	5905		7-5-5	1	
400D-26F	5905		7-5-3	2	
400D-26G	5905		7-3-4	1	
400D-44			7-1-1	1	
400D-6F			7-2-64	1	
400D-6H			7-2-57	1	
400D-6J	5930		7-2-30	1	
400D-6K	5940		7-2-31	1	
400D-60A	5950		7-5-6	2	
400D-65C			7-2-58	1	
400D-65C-1	5999		7-6-10	1	
400D-75F			7-2-52	1	
400D-75F-1	5999		7-5-12	1	
400D-75G			7-2-38	1	
400D-75G-1	5999		7-4-15	1	
400D-75G-2	5999		7-4-9	1	
400D-75H			7-2-4	1	
400H	6625-557-8261		7-1-	1	
400H-2A			7-1-14	1	
400L	6625-729-8360		7-1-	1	
42H-10%-PHENOLIC FORM	5950		7-4-14	1	
429-.125			7-2-13	1	
44F-16388	5935		7-2-16	2	
5P-1	5325		7-2-24	1	
5020-0137			7-1-13	1	
503-000-B2P0-28R	5910		7-2-28	1	
503-000-C0P0-10R	5910		7-6-8	1	
503-000-D2P0-33R	5910		7-2-29	1	
5060-0634	5940		7-1-2	2	
5060-0635	5940		7-1-3	2	
51A12272	5935		7-2-23	1	
510-061810-01	5310		7-2-	12	
510-081810-01	5310		7-1-	1	
557-000-U2P0-34R	5910		7-5-8	1	
5651	5960		7-2-9	1	
6AX5-GT	5960		7-2-21	1	
6CB6	5960		7-2-8	5	
			7-2-12		
6U8	5960		7-2-11	1	
61-6911	6130		7-2-70	1	
663UW20504	5910		7-2-1	2	
777	5340		7-2-65	1	
781	5340		7-2-35	1	
80994-H	5930		7-1-10	1	
9100-0050	5950		7-2-26	1	

MFR. OR MIL. PART NO.	STOCK NO.		FIG. AND INDEX NO.	QTY PER ART.	SOURCE CODE
	CLASS CODE	SERIAL OR PART NO.			
AN515-6-4	5305		7-1-	6	
AN526-632-14	5305		7-2-	2	
AN526-832-10	5905		7-1-	2	
AN526-832-8	5305		7-1-	5	
AN935-6	5310		7-2-	2	
AN960-6	5310		7-2-	1	
C-10-6.3K	5905		7-2-48	1	
CM15B680K	5910		7-4-13	1	
CM15E470J	5910		7-3-1	1	
CM15E560J	5910		7-3-5	1	
CM20B681K	5910		7-4-10	1	
CM35E472J	5910		7-6-5	1	
CS-2-125	5905		7-5-7	1	
CS-9941/PH151/7.5FT	6145		7-2-25	1	
CS-9941/PH151/7.5FT W/O PLUG	6145		7-2-25	1	
DC-1/2C-40	5905		7-5-9	1	
DC-1-10.31M	5905		7-6-9	1	
DC-1-10K	5905		7-6-4	1	
DC-1-166K	5905		7-4-4	1	
DC-1-90.5K	5905		7-4-3	1	
D27390	5910		7-2-20	2	
D32452	5910		7-2-17	3	
HD-5004	5960		7-5-11	2	
H02-400D	6625		7-1-	1	
H02-400D-FWR CORD	6145		7-2-25	1	
INSULOID C3	5340		7-2-33	1	
INSULOID N3	5340		7-2-2	3	
MAIN CHASSIS ASSEMBLY			7-1-15	1	
MDL-1	5920		7-2-71	1	
MS24663	5935		7-2-25	1	
MS35239-42	5305		7-2-	1	
N25-8.2K	5905		7-2-66	1	
PANEL ASSEMBLY			7-1-	1	
PKM 4P5	5910		7-2-34	1	
RC20GF100K	5905		7-6-6	2	
RC20GF104J	5905		7-2-46	1	
RC20GF104K	5905		7-4-2	1	
RC20GF125K	5905		7-2-67	1	
RC20GF153K	5905		7-3-2	1	
RC20GF225K	5905		7-2-61	1	
RC20GF275K	5905		7-2-44	1	
RC20GF335K	5905		7-2-73	1	
RC20GF470K	5905		7-2-40	5	
			7-6-2		
RC20GF471K	5905		7-2-36	2	
RC20GF474K	5905		7-2-37	2	
RC20GF511J	5905		7-5-10	1	
RC20GF560K	5905		7-6-7	1	
RC20GF561K	5905		7-2-43	2	
RC20GF684K	5905		7-2-49	1	
RC20GF825K	5905		7-2-62	1	
RC32GF100K	5905		7-2-69	1	
RC32GF114J	5905		7-2-55	1	
RC32GF124K	5905		7-4-5	1	
RC32GF183K	5905		7-2-74	1	
RC32GF2R7K	5905		7-2-42	2	
RC32GF224K	5905		7-2-41	2	
RC32GF242J	5905		7-4-11	2	
RC32GF332K	5905		7-2-53	1	
RC32GF334K	5905		7-4-8	1	
RC32GF473K	5905		7-2-50	4	
RC32GF510J	5905		7-5-1	1	
RC32GF563K	5905		7-4-6	1	
RC32GF683K	5905		7-4-1	1	
RC42GF103K	5905		7-2-51	1	
RC42GF184K	5905		7-4-7	1	
RC42GF273K	5905		7-4-12	4	
RC42GF682K	5905		7-2-59	1	
RC42GF822K	5905		7-2-56	2	
SCREW, ASSEMBLED WASHER	5305		7-2-	1	
SCREW, ASSEMBLED WASHER	5305		7-2-	8	
SCREW, ASSEMBLED WASHER	5305		7-2-	2	
S70375	5910		7-2-27	1	
0340-0089	5970		7-1-4	2	
0340-0090	5970		7-1-5	2	
0370-0035	5355		7-1-10	1	
1120-0005	6625		7-1-11	1	

HEWLETT-PACKARD STOCK NO. INDEX

H-P STOCK NUMBER	TOTAL QTY PER ART.	RECOM- MENDED SPARES	H-P STOCK NUMBER	TOTAL QTY PER ART.	RECOM- MENDED SPARES	H-P STOCK NUMBER	TOTAL QTY PER ART.	RECOM- MENDED SPARES
H02-400D	1		0689-5105	1	1	2100-0108	1	1
H02-400D-	1		0690-1001	1	1	2100-0136	1	1
PWR CORD			0690-1241	1	1	2100-0151	1	1
0130-0001	1	1	0690-1831	1	1	2110-0007	1	10
0130-0002	1	1	0690-2241	2	1	2140-0012	1	1
0130-0003	1	1	0690-3321	1	1	2190-0006	2	
0130-0006	1	1	0690-3341	1	1	2360-0003	6	
			0690-4731	4	1	2360-0012	2	
0140-0007	1	1	0690-5631	1	1	2370-0009	1	
0140-0014	1	1	0690-6831	1	1	2390-0001	1	
0140-0025	1	1	0693-1031	1	1	2390-0009	8	
0140-0039	1	1	0693-1841	1	1	2420-0001	14	
0140-0084	1	1	0693-2731	4	1	2520-0003	5	
0150-0009	1	1	0693-6821	1	1	2520-0006	2	
0150-0012	3	1	0693-8221	2	1	2550-0007	2	
0160-0002	1	1	0699-0005	2	1	2580-0003	1	
0160-0005	1	1	0727-0018	1	1	2900-0001	4	
0160-0013	2	1	0730-0029	1	1	3050-0100	1	
0160-0024	1	1	0730-0065	1	1	3101-0001	1	1
0160-0044	1	1	0730-0076	1	1	400D	1	
0170-0002	2	1	0730-0143	1	1	400D-1A	1	
0170-0040	1	1	0761-0001	1	1	400D-1B	1	
0170-0057	1	1	0813-0009	1	1	400D-19A	1	
0170-0063	1	1	0816-0017	1	1	400D-2	1	
0170-0064	2	1	1120-0005	1	1	400D-26C	1	1
0180-0025	3	1	1120-0091	1	1	400D-26F	2	1
0180-0028	2	1	1120-0301	1	1	400D-26G	1	1
0180-0033	2	1	1200-0008	2		400D-44	1	
0180-0063	1	1	1200-0009	6		400D-6F	1	
			1200-0020	1		400D-6H	1	
0340-0089	2		1220-0005	1		400D-6J	1	
0340-0090	2		1220-0010	1		400D-6K	1	
0370-0035	1		1251-0037	1		400D-60A	2	1
0380-0008	2		1390-0020	3		400D-65C	1	
0400-0013	1		1400-0015	1		400D-65C-1	1	
0686-5115	1	1	1400-0016	1		400D-75F	1	
0687-1001	2	1	1400-0025	1		400D-75F-1	1	
0687-1041	2	2	1400-0033	1		400D-75G	1	
0687-1251	1	1	1400-0074	1		400D-75G-1	1	
0687-1531	1		1400-0084	1		400D-75G-2	1	
0687-2251	1	1	1450-0020	1		400D-75H	1	
0687-2751	1	1	1450-0022	1		400H	1	
0687-3351	1	1	1882-0005	1	1	400H-2A	1	
0687-4701	5	2	1901-0027	2	2	400L	1	
0687-4711	2	1	1921-0010	1	1	5020-0137	1	
0687-4741	2	1	1923-0028	4	4	5060-0634	2	1
0687-5601	1	1	1930-0014	1	1	5060-0635	2	1
0687-5611	2	1	1933-0004	1	1	5080-0621	1	1
0687-6841	1	1	1940-0001	1	1	8120-0050	1	1
0687-8251	1	1	2100-0077	1	1	9100-0050	1	1
0689-1145	1	1	2100-0080	1	1	9140-0040	1	
0689-2425	2	1						

SECTION IX
REFERENCE DESIGNATION INDEX

REFERENCE DESIGNATION	FIGURE AND INDEX NUMBER	CLASS CODE OR STOCK NUMBER	MFR. OR MIL. PART NUMBER	H-P PART NUMBER
CR1	7-5-11	5960-	HD-5004	1901-0027
CR2	7-5-11	5960-	HD-5004	1901-0027
CR3	7-2-70	6130-	61-6911	1882-0005
C1	7-2-17	5910-	D32452	0180-0025
C100	7-2-63	5910-	160P10396	0160-0002
C101	7-2-60	5910-	148P47392	0170-0040
C102	7-5-8	5910-	557-000-U2P0-34R	0130-0002
C104	7-2-27	5910-	S70375	0170-0057
C105	7-2-20	5910-	D27390	0180-0028
C106	7-3-5	5910-	CM15E560J	0140-0014
C107	7-2-45	5910-	30D133A1	0180-0033
C108	7-3-1	5910-	CM15E470J	0140-0039
C14	7-2-28	5910-	503-000-B2P0-28R	0130-0006
C15	7-3-3	5910-	315-000-C0G0-100D	0150-0009
C16	7-2-29	5910-	503-000-D2P-033R	0130-0001
C17	7-2-17	5910-	D32452	0180-0025
C19	7-2-54	5910-	160P10494	0160-0013
C2	7-6-1	5910-	160P47396	0160-0005
C20	7-5-2	5910-	148P47491	0170-0064
C22	7-4-10	5910-	CM20B681K	0140-0007
C23	7-2-54	5910-	160P10494	0160-0013
C24	7-2-75	5910-	160P27296	0160-0044
C25	7-2-39	5910-	29C214A3-H-1038	0150-0012
C26	7-4-13	5910-	CM15E680K	0140-0025
C28	7-2-47	5910-	148P22394	0170-0063
C29	7-2-39	5910-	29C214A3-H-1038	0150-0012
C30	7-2-17	5910-	D32452	0180-0025
C31	7-5-2	5910-	148P47491	0170-0064
C32	7-2-1	5910-	663UW20504	0170-0002
C33	7-2-1	5910-	663UW20504	0170-0002
C34 D, H02	7-2-3	5910-	30D120A1	0180-0063
C34 H, L	7-2-3	5910-	30D133A1	0180-0033
C35	7-2-39	5910-	29C214A3-H-1038	0150-0012
C36	7-2-34	5910-	PKM 4P5	0160-0024
C39	7-2-20	5910-	D27390	0180-0028
C4	7-6-8	5910-	503-000-C0P0-10R	0130-0003
C5	7-6-5	5910-	CM35E472J	0140-0084
DS1	7-1-7	6240-	12	2140-0012
F1	7-2-71	5920-	MDL-1	2110-0007
L1	7-4-14	5950-	42μH-10%-PHENOLIC FORM	9140-0040
L10	7-5-6	5950-	400D-60A	400D-60A
L11	7-5-6	5950-	400D-60A	400D-60A
M1 D, H02	7-1-11	6625-	1120-0005	1120-0005
M1 H	7-1-11	6625-	1120-0301	1120-0301
M1 L	7-1-11	6625-	1120-0098	1120-0098
P1 D, H, L	7-2-25	6145-	CS-9941/PH151/7.5 FT	8120-0050
P1 H02	7-2-25	6145-	H02-400D-PWR CORD	H02-400D-PWR CORD
R1	7-2-55	5905-	RC32GF114J	0689-1145
R100	7-6-4	5905-	DC-1-10K	0730-0029
R101	7-6-3	5905-	2100-0151	2100-0151
R102	7-2-62	5905-	RC20GF825K	0687-8251

REFERENCE DESIGNATION	FIGURE AND INDEX NUMBER	CLASS CODE OR STOCK NUMBER	MFR. OR MIL. PART NUMBER	H-P PART NUMBER
R103	7-2-61	5905-	RC20GF225K	0687-2251
R104	7-5-3	5905-	400K-26F	400D-26F
R105	7-5-5	5905-	400D-26C	400D-26C
R106	7-5-9	5905-	DC-1/2C-40	0727-0018
R107	7-5-4	5905-	2100-0108	2100-0108
R108	7-5-3	5905-	400D-26F	400D-26F
R110	7-3-2	5905-	RC20GF153K	0687-1531
R111	7-3-4	5905-	400D-26G	400D-26G
R112	7-3-4	5905-	400D-26G	400D-26G
R113	7-3-4	5905-	400D-26G	400D-26G
R114	7-3-4	5905-	400D-26G	400D-26G
R115	7-3-4	5905-	400D-26G	400D-26G
R116	7-3-4	5905-	400D-26G	400D-26G
R117	7-2-59	5905-	RC42GF682K	0693-6821
R118	7-2-18	5905-	2100-0080	2100-0080
R119	7-2-19	5905-	2100-0136	2100-0136
R120	7-2-41	5905-	RC32GF224K	0690-2241
R121	7-2-42	5905-	RC32GF2R7K	0699-0005
R122	7-2-42	5905-	RC32GF2R7K	0699-0005
R20	7-2-56	5905-	RC42GF822K	0693-8221
R21	7-2-50	5905-	RC32GF473K	0690-4731
R22	7-2-56	5905-	RC42GF822K	0693-8221
R23	7-2-66	5905-	N25-8.2K	0761-0001
R24	7-2-40	5905-	RC20GF470K	0687-4701
R27	7-5-7	5905-	CS-2-12S	0813-0009
R30	7-2-67	5905-	RC20GF125K	0687-1251
R31	7-2-40	5905-	RC20GF470K	0687-4701
R32	7-2-50	5905-	RC32GF473K	0690-4731
R33	7-4-12	5905-	RC42GF273K	0693-2731
R34	7-4-12	5905-	RC42GF273K	0693-2731
R35	7-4-11	5905-	RC32GF242J	0689-2425
R36	7-2-73	5905-	RC20GF335K	0687-3351
R37	7-2-44	5905-	RC20GF275K	0687-2751
R38	7-2-43	5905-	RC20GF561K	0687-5611
R39	7-2-46	5905-	RC20GF104J	0687-1041
R4	7-6-9	5905-	DC-1-10.31M	0730-0143
R40	7-2-40	5905-	RC20GF470K	0687-4701
R41	7-2-50	5905-	RC32GF473K	0690-4731
R42	7-4-12	5905-	RC42GF273K	0693-2731
R43	7-4-12	5905-	RC42GF273K	0693-2731
R44	7-4-11	5905-	RC32GF242J	0689-2425
R47	7-2-43	5905-	RC20GF561K	0687-5611
R48	7-2-49	5905-	RC20GF684K	0687-6841
R49	7-2-40	5905-	RC20GF470K	0687-4701
R50	7-2-50	5905-	RC32GF473K	0687-4731
R51	7-2-53	5905-	RC32GF332K	0690-3321
R52	7-2-51	5905-	RC42GF103K	0693-1031
R53	7-5-10	5905-	RC20GF511J	0686-5115
R54	7-5-1	5905-	RC32GF510J	0689-5105
R55	7-4-7	5905-	RC42GF184K	0693-1841
R56	7-4-6	5905-	RC32GF563K	0690-5631
R57	7-2-48	5905-	C-10-6.3K	0816-0017
R58	7-4-5	5905-	RC32GF124K	0690-1241
R59	7-4-8	5905-	RC32GF334K	0690-3341
R6A	7-6-6	5905-	RC20GF100K	0687-1001
R6B	7-6-6	5905-	RC20GF100K	0687-1001
R6C	7-6-7	5905-	RC20GF560K	0687-5601
R60	7-2-74	5905-	RC32GF183K	0690-1831
R61	7-4-1	5905-	RC32GF683K	0690-6831
R62	7-4-4	5905-	DC-1-166K	0730-0076

REFERENCE DESIGNATION	FIGURE AND INDEX NUMBER	CLASS CODE OR STOCK NUMBER	MFR. OR MIL. PART NUMBER	H-P PART NUMBER
R63	7-4-2	5905-	RC20GF104K	0687-1041
R64	7-4-3	5905-	DC-1-90.5K	0730-0065
R66	7-2-68	5905-	2100-0077	2100-0077
R67	7-2-36	5905-	RC20GF471K	0687-4711
R68	7-2-69	5905-	RC32GF100K	0690-1001
R7	7-2-41	5905-	RC32GF224K	0690-2241
R83	7-2-37	5905-	RC20GF474K	0687-4741
R85	7-2-37	5905-	RC20GF474K	0687-4741
R86	7-6-2	5905-	RC20GF470K	0687-4701
R9	7-2-36	5905-	RC20GF471K	0687-4711
S1	7-3-6	5930-	3100-0251	3100-0251
S2	7-1-9	5930-	80994-H	3101-0001
T1	7-2-26	5950-	9100-0050	9100-0050
V1	7-2-12	5960-	6CB6	5080-0621
V2	7-2-8	5960-	6CB6	1923-0028
V3	7-2-8	5960-	6CB6	1923-0028
V4	7-2-8	5960-	6CB6	1923-0028
V5	7-2-8	5960-	6CB6	1923-0028
V6	7-2-21	5960-	6AX5GT	1930-0014
V7	7-2-10	5960-	12B4	1921-0010
V8	7-2-11	5960-	6U8	1933-0004
V9	7-2-9	5960-	5651	1940-0001
XDS1	7-1-8	6250-	2020-AE	1450-0022
XF1	7-2-72	5920-	342014	1400-0084
XV1	7-2-15	5935-	316PH-3702	1200-0009
XV2	7-2-15	5935-	316PH-3702	1200-0009
XV3	7-2-15	5935-	316PH-3702	1200-0009
XV4	7-2-15	5935-	316PH-3702	1200-0009
XV5	7-2-15	5935-	316PH-3702	1200-0009
XV6	7-2-23	5935-	51A12272	1200-0020
XV7	7-2-16	5935-	44F-16388	1200-0008
XV8	7-2-16	5935-	44F-16388	1200-0008
XV9	7-2-15	5935-	316PH-3702	1200-0009

APPENDIX **CODE LIST OF MANUFACTURERS (Sheet 1 of 2)**

The following code numbers are from the Federal Supply Code for Manufacturers Cataloging Handbooks H4-1 (Name to Code) and H4-2 (Code to Name) and their latest supplements. The date of revision and the date of the supplements used appear at the bottom of each page. Alphabetical codes have been arbitrarily assigned to suppliers not appearing in the H4 handbooks.

Code No.	Manufacturer	Address	Code No.	Manufacturer	Address	Code No.	Manufacturer	Address	Code No.	Manufacturer	Address
00000	U. S. A. Common	Any supplier of U.S.	07149	Filmohm Corp.	New York, N. Y.	49955	Raytheon Company	Lexington, Mass.	74970	E. F. Johnson Co.	Waseca, Minn.
00136	McCoy Electronics	Mount Holly Springs, Pa.	07233	Cinch-Graphix Co.	City of Industry, Calif.	52990	Rosen Controller Co.	Baltimore, Md.	75042	International Resistance Co.	Philadelphia, Pa.
00213	Sage Electronics Corp.	Rochester, N. Y.	07261	Avel Corp.	Los Angeles, Calif.	63743	Ward Leonard Electric	ML Vernon, N. Y.	75173	Jones, Howard B., Division	Chicago, Ill.
00334	Humidall Co.	Calton, Calif.	07263	Fairchild Semiconductor Corp.	Mountain View, Calif.	54294	Shallcross Mfg. Co.	Selma, N. C.	75378	James Knights Co.	Sandwich, Ill.
00335	Westrex Corp.	New York, N. Y.	07322	Minnesota Rubber Co.	Minneapolis, Minn.	55026	Simpson Electric Co.	Chicago, Ill.	75382	Kulka Electric Corporation	MT. Vernon, N. Y.
00373	Garlock Packing Co.,	Camden, N. J.	07387	The Birtcher Corp.	Los Angeles, Calif.	55933	Sonelone Corp.	Elmsford, N. Y.	75818	Lanz Electric Mfg. Co.	Chicago, Ill.
00656	Aerovox Corp.	New Bedford, Mass.	07700	Technical Wire Products	Springfield, N. J.	56137	Spaulding Fibre Co., Inc.	Toowanda, N. Y.	75915	Littelfuse Inc.	Des Plaines, Ill.
00719	Amf, Inc.	Harrisburg, Pa.	07910	Continental Device Corp.	Hawthorne, Calif.	56289	Sprague Electric Co.	North Adams, Mass.	76005	Lord Mfg. Co.	Erie, Pa.
00781	Aurical Radio Corp.	Boonton, N. J.	07933	Rheem Semiconductor Corp.	Mountain View, Calif.	59446	Telex, Inc.	St. Paul, Minn.	76210	C. W. Harwood	San Francisco, Calif.
00815	Northwestern Engineering Laboratories, Inc.	Burlington, Wis.	07966	Shockley Semi-Conductor Laboratories	Palo Alto, Calif.	59730	Thomas & Betts Co.	Bluffton, Ohio	76433	Micanoid Electronic Mfg. Corp.	Brooklyn, N. Y.
00853	Sangamo Electric Company,		07980	Boonton Radio Corp.	Boonton, N. J.	60741	Triplet Electrical Inc.		76487	James Miller Mfg. Co., Inc.	Malden, Mass.
	Ordid Division (Capacitors)	Marion, Ill.	08145	U. S. Engineering Co.	Los Angeles, Calif.	61775	Union Switch and Signal, Div. of	Westinghouse Air Brake Co.	76493	J. W. Miller Co.	Los Angeles, Calif.
00866	Goe Engineering Co.	Los Angeles, Calif.	08358	Burgess Battery Co.	Los Angeles, Calif.	62119	Universal Electric Co.	Swissvale, Pa.	76530	Monadnock Mills	San Leandro, Calif.
00891	Carl E. Holmes Corp.	Los Angeles, Calif.				62743	Ward-Leonard Electric Co.	ML Vernon, N. Y.	76545	Mueller Electric Co.	Cleveland, Ohio
01121	Allen Bradley Co.	Milwaukee, Wis.	08717	Staan Company	Niagara Falls, Ontario, Canada	64559	Western Electric Co., Inc.	New York, N. Y.	76658	Oak Manufacturing Co.	Crystal Lake, Ill.
01255	Litton Industries, Inc.	Beverly Hills, Calif.	08718	Canon Electric Co. Phoenix Div.	Phoenix, Ariz.	65092	Weston Inst. Div. of Daystrom, Inc.	Newark, N. J.	76804	Sandus Pacific Division of	
01281	TRW Semiconductor Corp.	Laurel, Calif.	08792	CBS Electronics Semiconductor Operations, Div. of C. B. S. Inc.	Lowell, Mass.	66295	Witte Manufacturing Co.	Chicago 23, Ill.	77075	Phacis Metals Co.	No. Hollywood, Calif.
01295	Texas Instruments, Inc.	Dallas, Texas	08884	Mel-Ram	Indianapolis, Ind.	66346	Wollensak Optical Co.	Rochester, N. Y.	77271	Pacific Instrument and	San Francisco, Calif.
01349	The Alliance Mfg. Co.	Alliance, Ohio	09026	Babcock Relays, Inc.	Costa Mesa, Calif.	70276	Allen Mfg. Co.	Hartford, Conn.	77250	Electronic Co.	South Pasadena, Calif.
01561	Chassi-Trak Corp.	Indianapolis, Ind.	09134	Texas Capacitor Co.	Houston, Texas	70309	Allied Control Co., Inc.	New York, N. Y.	77251	Phoenix Mfg. Co.	Chicago, Ill.
01589	Pacific Relays, Inc.	Van Nuys, Calif.	09145	Alpha Electronics	San Valley, Calif.	70319	Almetal Screw Prod. Co., Inc.	Garden City, N. Y.	77252	Philadelphia Steel and Wire Corp.	Philadelphia, Pa.
01930	Amerock Corp.	Rockford, Ill.	09250	Electro Assemblies, Inc.	Chicago, Ill.	70485	Atlantic India Rubber Works, Inc.	Chicago, Ill.	77342	Potter and Brumfield, Div. of American	Princeton, Ind.
01961	Pulse Engineering Co.	Santa Clara, Calif.	09569	Mallory Battery Co. of Canada, Ltd.	Toronto, Ontario, Canada	70563	Amperex Co.	Chicago, Ill.	77630	Radio Condenser Co.	Camden, N. J.
02114	Ferroxcube Corp. of America	Saugerties, N. Y.	09664	The Bristol Co.	Waterbury, Conn.	70903	Belden Mfg. Co.	Chicago, Ill.	77638	Radio Receiver Co., Inc.	Brooklyn, N. Y.
02286	Colt Mfg. Co.	Palo Alto, Calif.	10214	General Transistor Western Corp.	Los Angeles, Calif.	70998	Bird Electronic Corp.	Cleveland, Ohio	77764	Resistance Products Co.	Harrisburg, Pa.
02660	Amphenol-Borg Electronics Corp.	Chicago, Ill.				71002	Birnbach Radio Co.	New York, N. Y.	77963	Roberts Corp. of Calif.	Torrance, Calif.
02735	Radio Corp. of America, Semiconductor and Materials Div.	Somerville, N. J.	10411	Tri-Tal, Inc.	Berkeley, Calif.	71041	Boston Gear Works Div. of	Quincy, Mass.	78189	Shaperap Division of Illinois	
02771	Vocaline Co. of America, Inc.	Old Saybrook, Conn.	10646	Carborundum Co.	Niagara Falls, N. Y.	71218	Bud Radio Inc.	Cleveland, Ohio		Tool Works	Elgin, Ill.
02777	Hopkins Engineering Co.	San Fernando, Calif.	11236	CTS of Berne, Inc.	Berne, Ind.	71286	Canloc Fastener Corp.	Paramus, N. J.	78263	Signal Indicator Corp.	New York, N. Y.
03508	G. E. Semiconductor Products Dept.	Syracuse, N. Y.	11237	Chicago Telephone of California, Inc.	So. Pasadena, Calif.	71313	Allen D. Cardwell Electronic Prod. Corp.	Plainville, Conn.	78790	Strubbers-Dunn Inc.	Pittsboro, N. C.
03705	Aep Machine & Tool Co.	Dayton, Ohio	11312	Microwave Electronics Corp.	San Jose, Calif.	71400	Bussmann Fuse Div. of McGraw-Edison Co.	St. Louis, Mo.	78852	Transducer-Bremser & Co.	Chicago, Ill.
03797	Eidema Corp.	El Monte, Calif.	11334	Duncan Electronic, Inc.	Santa Ana, Calif.	71436	Chicago Condenser Corp.	Chicago, Ill.	78847	Tiller Mfg. Co.	San Francisco, Calif.
03797	Transitron Electronic Corp.	Wakfield, Mass.	11711	General Instrument Corporation Semiconductor Division	Newark, N. J.	71450	CTS Corp.	Elkhart, Ind.	78888	Staple Corp.	St. Marys, Pa.
03888	Pyrofilm Resistor Co.	Monroeville, N. J.	11717	Imperial Electronic, Inc.	Buena Park, Calif.	71468	Canon Electric Co.	Los Angeles, Calif.	78893	Standard Thompson Corp.	Waltham, Mass.
03949	Art Marine Motors, Inc.	Los Angeles, Calif.	11870	Melabs, Inc.	Palo Alto, Calif.	71471	Cinema Engineering Co.	Burbank, Calif.	78853	Tinnerman Products, Inc.	Cleveland, Ohio
04005	Arrow, Hart and Hegeman Elect. Co.	Hartford, Conn.	12659	Clasolab Mfg. Co.	Dover, N. H.	71482	C. P. Clare & Co.	Chicago, Ill.	78790	Transformer Engineers	Pasadena, Calif.
04062	Elmenco Products Co.	New York, N. Y.	12859	Nippon Electric Co., Ltd.	Tokyo, Japan	71590	Central Air Div. of Globe Union Inc.	Chicago, Ill.	78947	Uconite Co.	Hartford, Conn.
04272	Hu-Q Division of Aerovox	Myrtle Beach, S. C.	12903	Delta Semiconductor Inc.	Newport Beach, Calif.				79142	Veeber Rod, Inc.	Hartford, Conn.
04298	Elgin National Watch Co.,		13103	Thermolloy	Dallas, Texas				79251	Wenco Mfg. Co.	Chicago, Ill.
04404	Dynac Division of Hewlett-Packard Co.	Palo Alto, Calif.	13396	Telefunken (G. M. B. H.)	Mannheim, Germany	71700	The Cornish Wire Co.	Milwaukee, Wis.	79727	Continental-Wet Electronics Corp.	Philadelphia, Pa.
04651	Sylvania Electric Prods., Inc.	Mountain View, Calif.	13835	Midland Mfg. Co.	Kansas City, Kansas	71744	Chicago Miniature Lamp Works	Chicago, Ill.	79963	Zierick Mfg. Corp.	New Rochelle, N. Y.
04713	Motrola, Inc., Semiconductor Prod. Div.	Phoenix, Arizona	14099	Sea-Tech	Newbury Park, Calif.	71753	A.O. Smith Corp., Crowley Div.	West Orange, N. J.	80031	Meco Division of Sessions	Clark Co.
04732	Filtrol Co., Inc., Western Div.	Culver City, Calif.	14193	Calif. Resistor Corp.	Santa Monica, Calif.	71785	Cinch Mfg. Corp.	Chicago, Ill.	80120	Schulzer Alloy Products	Elizabeth, N. J.
04773	Automatic Electric Co.	Northlake, Ill.	14298	American Components, Inc.	Costa Mesa, Calif.	71984	Wood Corning Corp.	Midland, Mich.	80130	Times Facsimile Corp.	New York, N. Y.
04777	Automatic Electric Sales Corp.	Northlake, Ill.	14655	Connell Dubler Elec. Corp.	San Jose, Calif.	72092	Eitel McCullough, Inc.	San Bruno, Calif.	80131	Electronic Industries Association.	Any brand
04796	Sequoia Wire & Cable Co.	Redwood City, Calif.	14860	Williams Mfg. Co.	Livingston, N. J.	72136	Electric Motive Mfg. Co., Inc.	Wilmette, Conn.		IEEE meeting EIA standards	Washington, D. C.
04811	Precision Coil Spring Co.	El Monte, Calif.	15909	The Daven Co.	Spruce Pine, N. C.	71707	Colo Coil Co., Inc.	Providence, R. I.	80207	Unimax Switch, Div. of	Wallingford, Conn.
04870	P. M. Motor Company	Chicago 44, Ill.	16037	Spruce Pine Mica Co.	Lodi, N. J.	72354	John E. Fast & Co.	Chicago, Ill.	80223	United Transformer Corp.	New York, N. Y.
05006	Twentieth Century Plastics, Inc.	Los Angeles, Calif.	16352	Component Diode Corp.	Long Island City 1, N. Y.	72619	Dialight Corp.	Brooklyn, N. Y.	80248	Oxford Electric Corp.	Chicago, Ill.
05277	Westinghouse Electric Corp.,		16588	De Jui-Ampco Corporation	Long Island City 1, N. Y.	72656	General Ceramics Corp.	Keasbey, N. J.	80294	Bourns Laboratories, Inc.	Riverside, Calif.
	Semi-Conductor Dept.	Youngwood, Pa.				72659	General Instrument Corp., Semiconductor Div.	Newark, N. J.	80411	Acto Div. of Robertshaw	Fulton Controls Co.
05347	Ultronic, Inc.	San Mateo, Calif.	16758	Delco Radio Div. of G. M. Corp.	Kokomo, Ind.	72758	Guard-Hopkins	Oakland, Calif.	80486	All Star Products Inc.	Defiance, Ohio
05593	Ilumintronic Engineering Co.	Sunnyvale, Calif.	18873	E. I. DuPont & Co., Inc.	Wilmington, Del.	72765	Drake Mfg. Co.	Chicago, Ill.	80509	Avery Adhesive Label Corp.	Monteville, Calif.
05674	Barber Colman Co.	Rockford, Ill.	19315	Eclipse Pioneer, Div. of Bendix Aviation Corp.	Teleboro, N. J.	72825	Hugh H. Eby Inc.	Philadelphia, Pa.	80583	Hammelrud & Co., Inc.	New York, N. Y.
05728	Tiffen Optical Co.	Roslyn Heights, Long Island, N. Y.	19500	Thomas A. Edison Industries, Div. of McGraw-Edison Co.	West Orange, N. J.	72928	Gudean Co.	Chicago, Ill.	80640	Stevens, Asmelt, Co., Inc.	Boston, Mass.
05729	Metropolitan Telecommunications Corp.	Brooklyn, N. Y.	19701	Electra Manufacturing Co.	Kansas City, Mo.	72982	Robert M. Hadley Co.	Elgin, Pa.	81030	International Instruments, Inc.	New Haven, Conn.
05783	Stewart Engineering Co.	Santa Cruz, Calif.	20183	Electronic Tube Corp.	Philadelphia, Pa.	73076	Erle Resistor Corp.	Princeton, Ind.	81073	Grayhill Co.	LaGrange, Ill.
05820	Wakfield Engineering Inc.	Wakfield, Mass.	21226	Executive, Inc.	New York, N. Y.	73061	Hansen Mfg. Co., Inc.	Chicago, Ill.	81095	Triad Transformer Corp.	Venice, Calif.
06004	The Bassick Co.	Bridgeport, Conn.	21520	Fanstel Metallurgical Corp.	Chicago, Ill.	73138	Helipot Div. of Beckman Instruments, Inc.	Fullerton, Calif.	81312	Winchester Electronics Co., Inc.	Norwalk, Conn.
06175	Bausch and Lomb Optical Co.	Rochester, N. Y.	21335	The Fabrite Bearing Co.	New Britain, Conn.	73293	Hughes Products Division of Hughes Aircraft Co.	Newport Beach, Calif.	81349	Military Specification	-----
06402	E. T. A. Products Co. of America	Chicago, Ill.	21964	Fed. Telephone and Radio Corp.	Clifton, N. J.	73445	Amperex Electronic Co., Div. of North American Philips Co., Inc.	Hicksville, N. Y.	81415	Waylon Products, Inc.	Cleveland, Ohio
06540	Amaton Electronic Hardware Co. Inc.	New Rochelle, N. Y.	24446	General Electric Co.	Schenectady, N. Y.	73490	Beckman Helipot Corp.	So. Pasadena, Calif.	81453	Raytheon Mfg. Co., Industrial Components	Newton, Mass.
06555	Beede Electrical Instrument Co., Inc.	Pennacook, N. H.	24655	Genes Reproducer Corp.	West Concord, Mass.	73506	Bradley Semiconductor Corp.	Hawden, Conn.	81483	International Rectifier Corp.	El Segundo, Calif.
06571	U. S. Sensor Division of Nuclear Corp. of America	Phoenix, Arizona	24662	Grobel File Co. of America, Inc.	Carlsbad, N. J.	73559	Carling Electric, Inc.	Hartford, Conn.	81541	The Angus Products Co.	Cambridge, Mass.
06612	Torrington Mfg. Co., West Div.	Van Nuys, Calif.	24692	Hamilton Watch Co.	Palto Alto, Calif.	73682	George K. Garrett Co., Inc.	Philadelphia, Pa.	81860	Berry Controls, Inc.	Watertown, Mass.
07115	Corning Glass Works	Bradford, Pa.	33173	G. E. Receiving Tube Dept.	Owensboro, Ky.	73734	Federal Screw Prod. Co.	Chicago, Ill.	82042	Carier Parts Co.	Slovak, Ill.
07126	Digital Co.	Pasadena, Calif.	35434	Lectrohm Inc.	Chicago, Ill.	73743	Fischer Special Mfg. Co.	Chicago, Ill.	82142	Jellers Electronics Division of	Du Bois, Pa.
07137	Transistor Electronics Corp.	Minneapolis, Minn.	35492	Slawny Corp.	Hawkesbury, Ontario, Canada	73793	The General Industries Co.	Elyria, Ohio	82170	Allen B. DuMont Labs, Inc.	Clifton, N. J.
07138	Westinghouse Electric Corp.	Elmira, N. Y.	35543	Mechanical Industries Prod. Co.	Akron, Ohio	73846	Goshen Stamping & Tool Co.	Goshen, Ind.	82219	Sylvania Electric Prod. Inc.	Emporium, Pa.
	Electronic Components Dept.		48920	Minature Precision Bearings, Inc.	Keene, N. H.	73859	JFD Electronics Corp.	Brooklyn, N. Y.	82376	Astron Co.	East Newark, N. J.
			48990	C. A. Morgan Co.	Englewood, Colo.	74276	Signaline Inc.	Neptune, N. J.	82389	Switchcraft, Inc.	Chicago, Ill.
			46555	Ohmite Mfg. Co.	Skokie, Ill.	74455	J. H. Wines and Sons	Winchester, Mass.	82647	Metals and Controls, Inc., Div. of	
			47904	Polaroid Corp.	Cambridge, Mass.	74861	Industrial Condenser Corp.	Chicago, Ill.		Texas Instruments, Inc.,	
			48620	Precision Thermometer and Inst. Co.	Philadelphia, Pa.	74868	R. F. Products Division of Amphenol-Borg Electronics Corp.	Danbury, Conn.		Spencer Prods.	Attleboro, Mass.

APPENDIX **CODE LIST OF MANUFACTURERS (Sheet 2 of 2)**

Code No.	Manufacturer	Address	Code No.	Manufacturer	Address	Code No.	Manufacturer	Address	Code No.	Manufacturer	Address
82866	Research Products Corp.	Madison, Wis.	89636	Carter Parts Div. of Economy Baler Co.	Chicago, Ill.	95263	Leecraft Mfg. Co., Inc.	New York, N.Y.	THE FOLLOWING H-P VENDORS HAVE NO NUMBER ASSIGNED IN THE LATEST SUPPLEMENT TO THE FEDERAL SUPPLY CODE FOR MANUFACTURERS HANDBOOK.		
82877	Rotron Manufacturing Co., Inc.	Woodstock, N.Y.				95264	Lenco Electronics, Inc.	Burbank, Calif.			
82883	Vector Electronic Co.	Glendale, Calif.	89665	United Transformer Co.	Chicago, Ill.	95265	National Coil Co.	Shenandoah, Wyo.			
83053	Western Washer Mfg. Co.	Los Angeles, Calif.	90179	U. S. Rubber Co., Mechanical Goods Div.	Passaic, N.J.	95275	Villaman, Inc.	Bridgeport, Conn.			
83058	Carr Fastener Co.	Cambridge, Mass.				95348	Cordas Corp.	Bloomfield, N.J.	C0000	JFD Electronics Corp.	Van Nuys, Calif.
83086	New Hampshire Ball Bearing, Inc.	Peterborough, N.H.	90970	Bearing Engineering Co.	San Francisco, Calif.	95354	Melhode Mfg. Co.	Chicago, Ill.	G0000	Tranes Company	Mountain View, Calif.
83125	Pyramid Electric Co.	Darlington, S.C.	91260	Connor Spring Mfg. Co.	San Francisco, Calif.	95987	Weckesser Co.	Chicago, Ill.	10000	Western Devices, Inc.	Inglewood, Calif.
83148	Electro Cords Co.	Los Angeles, Calif.	91345	Miller Dial & Nameplate Co.	El Monte, Calif.	96067	Huggins Laboratories	Sunnyvale, Calif.	J0000	Winchester Electronics, Inc.	
83186	Victory Engineering Corp.	Union, N.J.	91418	Radio Materials Co.	Chicago, Ill.	96095	Hi-Q Division of Aerovox	Orlean, N.Y.			
83298	Bendix Corp., Red Bank Div.	Red Bank, N.J.	91506	Augat Brothers', Inc.	Attleboro, Mass.	96256	Thordarson-Meissner Div. of Maguire Industries, Inc.	Mt. Carmel, Ill.	0000F	Malco Tool and Die	Santa Monica, Calif.
83315	Hubbell Corp.	Mundelein, Ill.	91637	Dale Electronics, Inc.	Columbus, Nebr.	96296	Solar Manufacturing Co.	Los Angeles, Calif.	0000M	Western Coil Div. of Automatic Ind., Inc.	Redwood City, Calif.
83330	Smith, Herman H., Inc.	Brooklyn, N.Y.	91662	Elco Corp.	Philadelphia, Pa.	96330	Carlton Screw Co.	Chicago, Ill.	0000N	Nahm-Bros. Spring Co.	San Leandro, Calif.
83385	Central Screw Co.	Chicago, Ill.	91737	Grenair Mfg. Co., Inc.	Wakefield, Mass.	96341	Microwave Associates, Inc.	Burlington, Mass.	0000P	Ty-Car Mfg. Co., Inc.	Holliston, Mass.
83501	Gavitt Wire and Cable Co., Div. of Amerace Corp.	Brookfield, Mass.	91827	K. F. Development Co.	Redwood City, Calif.	96501	Excel Transformer Co.	Oakland, Calif.	0000W	Webster Electronics Co. Inc.	New York, N.Y.
83594	Burroughs Corp.		91929	Minneapolis-Honeywell Regulator Co.	Freeport, Ill.	97464	Industrial Retaining Ring Co.	Irvine, N.J.	0000Z	Willow Leather Products Corp.	Newark, N.J.
83740	Eveready Battery	Plainfield, N.J.				97539	Automatic and Precision Mfg. Co.	Yonkers, N.Y.	000A	British Radio Electronics Ltd.	Washington, D.C.
83777	Model Eng. and Mfg., Inc.	Huntington, Ind.	92160	Tri-Connector Corp.	Peasbody, Mass.	97966	CBS Electronics, Div. of C. B. S., Inc.	Danvers, Mass.	000AB	ETA	Indiana
83821	Loyd Scruggs Co.	Festus, Mo.	92196	Universal Metal Prod., Inc.	Bassett Pointe, Calif.	97979	Reon Resistor Corp.	Yonkers, N.Y.	000AC	Indiana General Corp., Elect. Div.	Van Nuys, Calif.
84171	Arco Electronics, Inc.	New York, N.Y.	92367	Elgeest Optical Co., Inc.	Rochester, N.Y.	98141	Axel Brothers Inc.	Yonkers, N.Y.	000AD	Curtis Insulvent Inc.	Mt. Kisco, N.Y.
84336	A. J. Glesner Co., Inc.	San Francisco, Calif.	92607	Tinsolite Insulated Wire Co.	Tarrytown, N.Y.	98159	Rubber Tech, Inc.	Jamaica, N.Y.	000BB	Precision Instrument Components Co.	
84411	Good All Electric Mfg. Co.	Ogallala, Neb.	93332	Sylvania Electric Prod. Inc., Semiconductor Div.	Woburn, Mass.	98270	Francis L. Mosley	Pasadena, Calif.	000MM	Rubber Eng. & Development	Hayward, Calif.
84970	Sarkes Tarzian, Inc.	Bloomington, Ind.	93369	Robbins and Myers, Inc.	New York, N.Y.	98278	Microdial, Inc.	So. Pasadena, Calif.	000NN	A "N" D Manufacturing Co.	San Jose 27, Calif.
85454	Bonton Molding Company	Bonton, N.J.	93410	Stevens Mfg. Co., Inc.	Mansfield, Ohio	98291	Sealectro Corp.	Mamaroneck, N.Y.	000QQ	Cooltron	Oakland, Calif.
85471	A. B. Boyd Co.	San Francisco, Calif.	93788	Howard J. Smith Inc.	Port Monmouth, N. J.	98405	Carad Corp.	Redwood City, Calif.	000RR	Radio Industries	Des Plaines, Ill.
85474	R. M. Biacamonte & Co.	San Francisco, Calif.	93929	G. V. Controls	Livingston, N. J.	98731	General Mills	Minneapolis, Minn.	000SS	Control of Elgin Watch Co.	Burbank, Calif.
85660	Koiled Kords, Inc.	New Haven, Conn.	93983	Insuline-Van Norman Ind., Inc. Electronic Division	Manchester, N. H.	98821	North Hills Electric Co.	Minneapolis, Minn.	000WW	California Eastern Lab.	Burlingame, Calif.
85911	Seamless Rubber Co.	Chicago, Ill.	94137	General Cable Corp.	Bayonne, N. J.	98825	Clevite Transistor Prod. Div. of Clevite Corp.	Waltham, Mass.	000XX	Melhode Electronics, Inc.	Chicago 31, Ill.
86197	Clifton Precision Products	Clifton Heights, Pa.	94144	Raytheon Mfg. Co., Industrial Components Div., Receiving Tube Operation	Quincy, Mass.	98978	International Electronic Research Corp.	Burbank, Calif.	000YY	S. K. Smith Co.	Los Angeles 45, Calif.
86579	Precision Rubber Products Corp.	Dayton, Ohio	94145	Raytheon Mfg. Co., Semiconductor Div., California Steel Plant	Newton, Mass.	99109	Columbia Technical Corp.	New York, N.Y.			
86684	Radio Corp. of America, RCA Division	Harrison, N.J.	94148	Scientific Radio Products, Inc.	Loveland, Colo.	99313	Varian Associates	Palo Alto, Calif.			
87216	Phico Corporation (Lansdale Division)	Lansdale, Pa.	94154	Tung-Sol Electric, Inc.	Newark, N.J.	99515	Marshall Industries, Electron Products Division	Pasadena, Calif.			
87473	Western Fibrous Glass Products Co.	San Francisco, Calif.	94197	Curtiss-Wright Corp., Electronics Div.	East Paterson, N.J.	99707	Control Switch Division, Controls Co. of America	El Segundo, Calif.			
87664	Van Waters & Rogers Inc.	Seattle, Wash.	94222	Southco Div. of S. Chester Corp.	Lester, Pa.	99800	Delevan Electronics Corp.	East Aurora, N.Y.			
87930	Tower Mfg. Corp.	Providence, R. I.	94310	Tri Ohm Prod. Div. of Model Engineering and Mfg. Co.	Chicago, Ill.	99848	Wilco Corporation	Indianapolis, Ind.			
88140	Cutter-Hammer, Inc.	Lincoln, Ill.	94682	Worcester Pressed Aluminum Corp.	Worcester, Mass.	99934	Renbrandt, Inc.	Boston, Mass.			
88220	Gould-National Batteries, Inc.	St. Paul, Minn.				99942	Hollman Semiconductor Div. of Hollman Electronics Corp.	Evanston, Ill.			
88598	General Mills, Inc.	Buffalo, N.Y.	95023	Philbrick Researchers, Inc.	Boston, Mass.	99957	Technology Instrument Corp. of Calif.	Newbury Park, Calif.			
89231	Graybar Electric Inc. Co.	Oakland, Calif.	95236	Allies Products Corp.	Miami, Fla.						
89473	General Electric Distributing Corp.	Schenectady, N.Y.	95238	Continental Connector Corp.	Woodside, N.Y.						



MODELS 400D/H/L, H02-400D

VACUUM TUBE VOLTMETER

Manual Serial Prefixed: 310- (400D/H02-400D)
313- (400H/L)

(hp Part No. 400D/H/L-902)

To adapt this manual to instruments with earlier serial numbers check for errata below, and make changes shown in tables.

NOTE

These Manual Backdating Changes make this manual applicable to earlier instruments. Instrument-component values that differ from those in this manual, yet are not listed in the Backdating Changes, should be replaced using the part numbers given in this manual.

Instrument Serial Nos.	Make Manual Changes	Instrument Serial Nos.	Make Manual Changes
(400D/H02-400D) Above 310-45571	Manual applies	(400DR) Above 310-45571	4
(400H/L) Above 313-22177	Manual applies	(400DR) Below 310-45570	1, 4
(400D/H02-400D) Below 310-45570	1	(400HR/LR) Above 313-22177	4
(400H/L) Below 313-22176	1	(400HR/LR) Below 313-22176	1, 4
(400L) Below 048-13256	1, 2	(400HR) Below 017-12026	1, 5
(400H) Below 017-12026	1, 3	(400LR) Below 048-13256	1, 5

CHANGE #1

Section V, Figure 5-10, Voltmeter Schematic Diagram

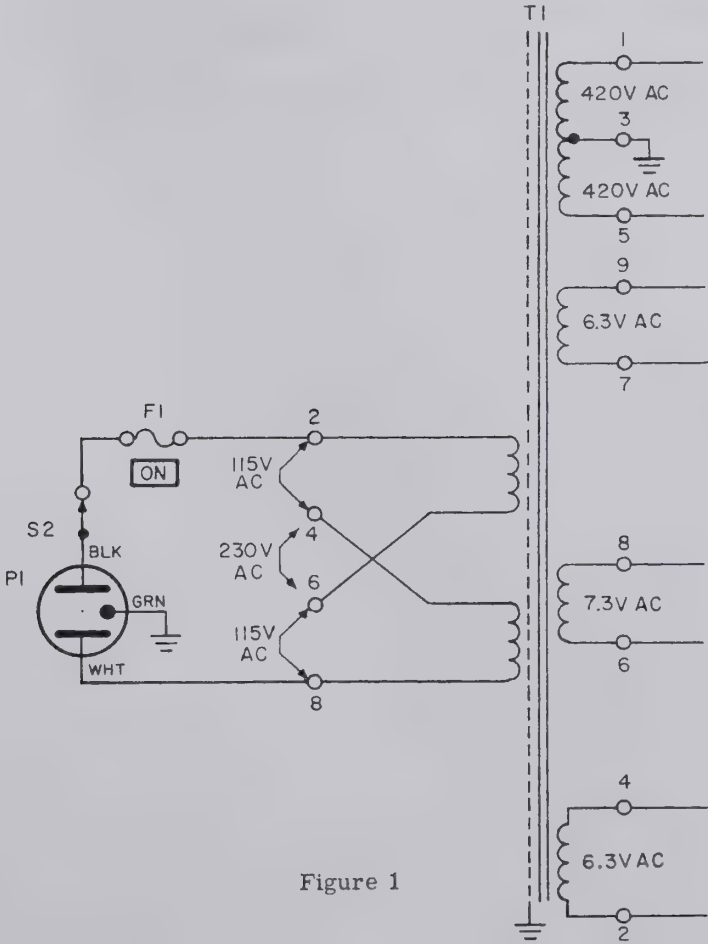


Figure 1

CHANGE #2

Section VII, Figures 7-1-11 and 7-1-14

Multimeter, Replacement: Change ~~hp~~ Part No. to read 1120-0081.Panel, Front: Change ~~hp~~ Part No. to read 400H-2.

Section VIII, Numerical Indexes

Change MFR. OR MIL. PART NO. 1120-0098 to read 1120-0081.

Change MFR. OR MIL. PART NO. 400H-2A to read 400H-2.

Section IX, Reference Designation Index

Change Reference Designation M1 L MFR. OR MIL. PART NO. and -HP-PART NUMBER to read 1120-0081.

CHANGE #3

Section VII, Figures 7-1-11 and 7-1-14

Multimeter, Replacement: Change ~~hp~~ Part No. to read 1120-0048.Panel, Front: Change ~~hp~~ Part No. to read 400H-2.

Section VIII, Numerical Indexes

Change MFR. OR MIL. PART NO. 1120-0301 to read 1120-0048.

Change MFR. OR MIL. PART NO. 400H-2A to read 400H-2.

Section IX, Reference Designation Index

Change Reference Designation M1 H MFR. OR MIL. PART NO. and -HP-PART NUMBER to read 1120-0048.

CHANGE #4

Replacement parts common to rack mount instruments (400DR/HR/LR) only:

ADD

Description	hp Part No.
Dust Cover	5000-0627
Panel, Front - DR	400D-2R
HR	400H-2B
LR	400L-2B
Bracket, Panel Mtg.	400D-12B
Insulator, Bushing	400D-41A
Bracket, Mtg. (HR/LR)	5020-0243

DELETE

Description	hp Part No.
Cabinet Ass'y	400D-44
Panel, Front - D	400D-2
H/L	400H-2A
Bezel	5020-0137

CHANGE #5

Replacement Parts:

Multimeter Replacement: Change ~~hp~~ Stock No. to read (HR) 1120-0048; (LR) 1120-0081.Panel, Front: Change ~~hp~~ Stock No. to read (HR) 400H-2R; (LR) 400L-2R.

All other additions and deletions in CHANGE #5 apply.



OPERATING AND SERVICE MANUAL

(HP PART NO. 400D/H/L-903)

MODEL 400D

SERIALS PREFIXED: 310-

MODEL 400H

SERIALS PREFIXED: 313-

MODEL 400L

SERIALS PREFIXED: 313-

AND

SPECIF. H02-400D

SERIALS PREFIXED: 310-

VACUUM TUBE VOLTMETER

Appendix C, Manual Backdating
Changes, adapts this manual to:

Models 400D/H02-400D,	Serial Nos. 313-28977 and below
Models 400H/L,	Serial Nos. 310-52371 and below
Models 400DR/HR/LR,	All Serial Nos.

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P.O. Box 301, Loveland, Colorado, 80537 U.S.A.

TABLE OF CONTENTS

Section	Page	Section	Page
I GENERAL DESCRIPTION	1-1	5-22 Testing Voltmeter Performance . .	5-5
1-1 Introduction	1-1	5-24 Calibration and Frequency Response Adjustments	5-8
1-4 Description	1-1	VI ILLUSTRATED PARTS	
1-11 Accessories	1-2	BREAKDOWN	6-1
II INSTALLATION	2-1	6-1 General	6-1
2-1 Unpacking and Inspection	2-1	VII GROUP ASSEMBLY PARTS	
2-3 Line Voltage Requirement	2-1	BREAKDOWN	7-1
2-5 Power Line Connections	2-1	7-1 Vacuum Tube Voltmeter 400D/H/L	7-1
2-8 Installation	2-1	7-2 Main Chassis Assembly	7-3
2-10 Operation Check	2-1	7-3 Range Switch Assembly 400D-19A	7-8
III OPERATING INSTRUCTIONS	3-1	7-4 Printed Circuit Board Assembly 400D-75G	7-9
3-1 Instrument Turn-On	3-1	7-5 Printed Circuit Board Assembly 400D-75F	7-11
3-3 General Operating Information	3-1	7-6 Printed Circuit Board Assembly 400D-65C	7-12
3-12 Low-Level Measurements and Ground Currents	3-2	VIII NUMERICAL INDEXES	8-1
3-14 Measurement of Voltage	3-2	Part No. Numerical Index	8-1
3-17 Measurement of Decibels	3-3	Hewlett-Packard Stock No. Index	8-2
3-20 Impedance Correction Graph	3-3	IX REFERENCE DESIGNATION INDEX	9-1
3-22 Use of Voltmeter Amplifier	3-4		
IV CIRCUIT DESCRIPTION	4-1		
4-1 Block Diagram	4-1		
4-3 Input Voltage Divider and Step Attenuator	4-1		
4-7 Broadband Voltmeter Amplifier	4-1		
4-10 Indicating Meter Circuit	4-1		
4-14 Power Supply	4-2		
V MAINTENANCE	5-1		
5-1 Scope	5-1		
5-3 Precautions	5-1		
5-5 Test Equipment Required	5-1		
5-7 Meter Zero Adjustment	5-1		
5-9 Cabinet Removal	5-2		
5-10 Tube Replacement	5-2		
5-13 Replacement of Special Parts	5-2		
5-17 Trouble Shooting	5-3		
5-20 Testing the Power Supply	5-3		

Appendix

A CODE LIST OF MANUFACTURERS

Appendix

B SALES AND SERVICE OFFICES

Appendix

C MANUAL BACKDATING CHANGES

LIST OF ILLUSTRATIONS

Number	Title	Page	Number	Title	Page
1-1.	Vacuum Tube Voltmeters Models 400D, 400H, and 400L	1-0	5-6.	Test Setup for Calibration Check and Adjustments	5-7
1-2.	Table of Specifications	1-1	5-7.	Test Setup for Frequency Response Check and Adjustment	5-8
3-1.	Voltmeter Front Panel, Showing Controls and Connectors	3-0	5-8.	Voltage and Resistance Diagram	5-10
3-2.	Effect of Harmonics on Voltage Measurements	3-1	5-9.	Diagram of RANGE Switch	5-11
3-3.	Test Setup for Avoiding Ground Loop	3-2	5-10.	Voltmeter Schematic Diagram	5-13
3-4.	Impedance Correction Graph	3-5	7-1.	400D/H/L Vacuum Tube Voltmeter	7-1
4-1.	Voltmeter Block Diagram	4-0	7-2.	Main Chassis Assembly (Sheet 1 of 2)	7-3
4-2.	Simplified Schematic of Meter Bridge Circuit	4-2	7-2.	Main Chassis Assembly (Sheet 2 of 2)	7-5
5-1.	Test Equipment Required	5-1	7-3.	RANGE Switch Assembly	7-8
5-2.	Adjustments Required When Tubes Are Replaced	5-2	7-4.	Printed Circuit Board Assembly Part No. 400D-75G	7-9
5-3.	Left Side View of Voltmeter Chassis	5-4	7-5.	Printed Circuit Board Assembly Part No. 400D-75F	7-10
5-4.	Right Side View of Voltmeter Chassis	5-5	7-6.	Printed Circuit Board Assembly Part No. 400D-65C	7-12
5-5.	Trouble-Shooting Procedure	5-6			

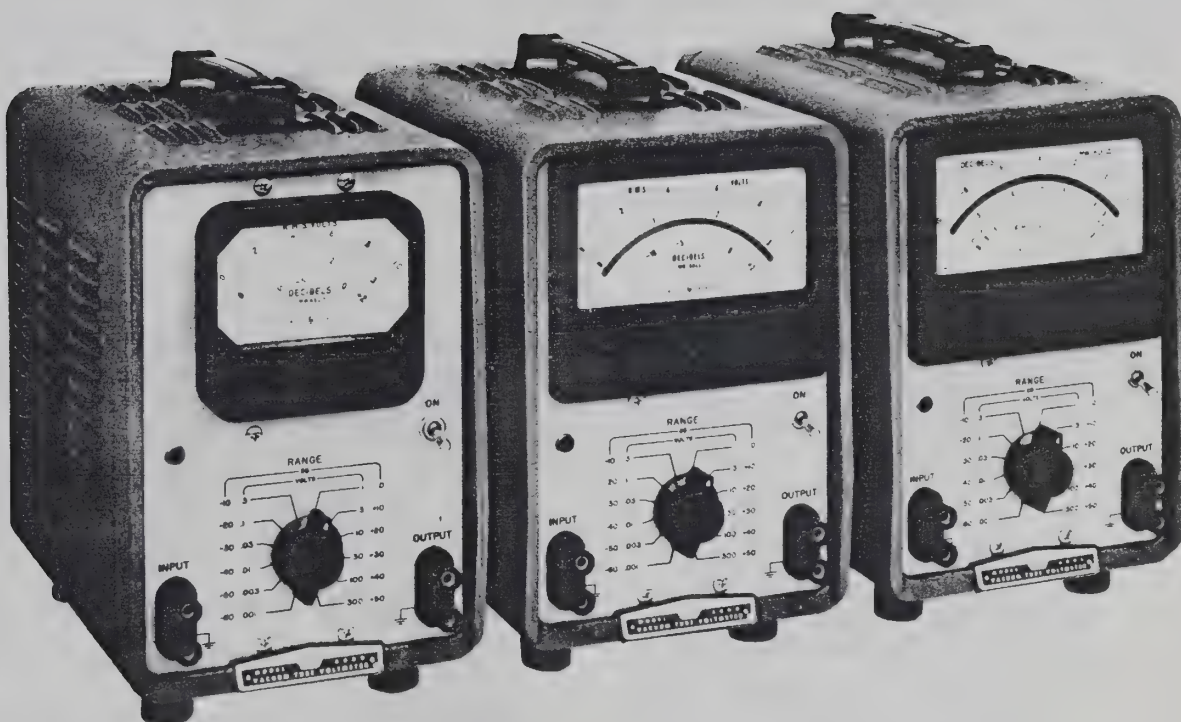


Figure 1-1. Vacuum Tube Voltmeters Models 400D, 400H, 400L

SECTION I

GENERAL DESCRIPTION

1-1. INTRODUCTION. (See figure 1-1.)

1-2. This manual contains operating and servicing instructions, and a parts breakdown, for the Models 400D, 400H, and 400L Vacuum Tube Voltmeters manufactured by the Hewlett-Packard Company. The Model 400D Voltmeter is similar to a military counterpart, Electronic Voltmeter ME-30A/U, in appearance and operation, but contains modified electrical circuits to obtain improved performance. Applicable Federal Stock Numbers for the voltmeters are as follows:

Model 400D: 6625-643-1670
Model 400H: 6625-557-8261
Model 400L: 6625-729-8360

1-3. The Models 400D, 400H, and 400L Voltmeters are the same except for the differences listed in Figure 1-2.

a. The front panel meters are different in each model, as described in paragraph 1-6.

b. The accuracy specifications are different for each model, as described in figure 1-2.

1-4. DESCRIPTION.

1-5. The Hewlett-Packard Models 400D, 400H, and 400L Vacuum Tube Voltmeters are general purpose, portable electronic a-c voltmeters of high sensitivity and stability. They are suited to both laboratory and field use. Models 400D/H measure a-c voltages from 0.001 to 300 volts and Model 400L from .003 to 300 volts rms full scale, with a frequency bandwidth covering 10 cps to 4 megacycles. The voltmeters are compact, accurate, and rugged and have fast meter response, high input impedance, stable calibration accuracy, and freedom from the effects of normal line voltage variations. The voltmeters are designed for long instrument life with a minimum of servicing.

a. Voltage Range: 400D/H - 0.1 millivolt to 300 volts; 400L - 0.3 millivolt to 300 volts, in 12 ranges providing full-scale readings of the following voltages:

0.001	0.100	10.00
0.003	0.300	30.00
0.010	1.000	100.00
0.030	3.000	300.00

b. Decibel Range: -72 to +52 db, in 12 ranges.

c. Frequency Range: 10 cps to 4 mc.

d. Input Impedance: 10 megohms shunted by 15 pf (15 μ mf) on ranges 1.0 volt to 300 volts; 25 pf on ranges 0.001 volt to 0.3 volt.

e. Stability: Line voltage variations of $\pm 10\%$ do not reduce the specified accuracy, and line voltage transients are not reflected in the meter reading. Electron tube deterioration to 75% of normal transconductance affects accuracy less than 0.5% from 20 cps to 1 mc.

f. Amplifier: OUTPUT terminals are provided so that the voltmeter can be used to amplify small signals or to enable monitoring of waveforms under test with an oscilloscope. Output voltage is approximately 0.15 volt rms on all ranges with full-scale meter deflection. Amplifier frequency response is same as the voltmeter. Internal impedance is approximately 50 ohms over entire frequency range.

g. Accuracy: Model 400D -

$\pm 2\%$ of full scale, 20 cps to 1 mc;
 $\pm 3\%$ of full scale, 20 cps to 2 mc;
 $\pm 5\%$ of full scale, 10 cps to 4 mc.

Model 400H -

$\pm 1\%$ of full scale, 50 cps to 500 kc;
 $\pm 2\%$ of full scale, 20 cps to 1 mc;
 $\pm 3\%$ of full scale, 20 cps to 2 mc;
 $\pm 5\%$ of full scale, 10 cps to 4 mc.

Model 400L -

$\pm 2\%$ of reading or $\pm 1\%$ of full scale, whichever is more accurate, 50 cps to 500 kc.
 $\pm 3\%$ of reading or $\pm 2\%$ of full scale, whichever is more accurate, 20 cps to 1 mc.
 $\pm 4\%$ of reading or $\pm 3\%$ of full scale, whichever is more accurate, 20 cps to 2 mc.
 $\pm 5\%$ of reading 10 cps to 4 mc.

h. Power Requirement: 115/230 volts $\pm 10\%$, 50 to 1000 cps, approximately 100 watts.

i. Size: 11-3/4 in. high, 7-1/2 in. wide, 12 in. deep.

j. Weight: 18 lbs; shipping weight approximately 23 lbs.

Figure 1-2. Table of Specifications

1-6. Each model voltmeter has three calibrated scales on the panel meter. The Models 400D and 400H have two linear VOLTS scales, 0 to 1 and 0 to 3, and one DECIBELS scale, -12 to +2 db. The meters used in the Models 400H and 400L are larger and include a mirror to eliminate parallax in viewing and to facilitate use of the higher scale calibration accuracy of these models. The Model 400L VOLTS scales are logarithmic in calibration, from 0.3 to 1 and 0.8 to 3; and the DECIBELS scale is linear. In all models, the VOLTS scales are calibrated to indicate the root-mean-square (rms) value of an applied sine wave. Actual meter deflection is proportional to the average value of the applied signal, thereby minimizing additional meter deflection due to noise and harmonic distortion.

1-7. A voltmeter output signal is provided at the front panel OUTPUT terminals. This output is proportional to the meter reading and has a waveshape similar to the applied signal. This signal level is about 0.15 volts rms for a full-scale meter reading, regardless of the input signal level. The internal impedance at the OUTPUT terminal is 50 ohms over the full frequency range. High-impedance loads (above 100K) will not adversely affect the accuracy of the voltmeter. This output is valuable for increasing the sensitivity of bridges, etc., where distortion added to the waveform is not a factor.

1-8. The voltmeter chassis is constructed of aluminum alloy throughout. The panel is finished in non-reflecting, light-grey baked enamel; the cabinet is finished in dark-blue, baked wrinkle paint. The cabinet is equipped with rubber feet and a leather carrying handle. Control markings on the front panel are engraved and black filled. INPUT and OUTPUT terminals are special binding posts which accept either bare wire or banana plugs; the 3/4-inch spacing between binding posts accepts standard dual-banana plugs. The "ground" side of the INPUT and OUTPUT terminals is connected to the instrument chassis which is in turn connected to the power line ground through the third (round) prong of the plug on the power cable.

1-9. The voltmeter is equipped with a non-detachable power cord. Test leads, which may be plain wire leads or coaxial cable, and test probes must be supplied by the user.

1-10. Instruments designated Models 400DR, 400HR, and 400LR are rack mount configurations of the 400D, 400H, and 400L, respectively. They are identical to their cabinet model counterparts in every other respect. They are designed to be mounted in a standard 19 inchwide x 7 inch high relay rack space. Refer to Appendix C for Replacement Parts information.

1-11. ACCESSORIES.

1-12. Accessory instruments for the voltmeter are available (not supplied) to increase its range of operation and application, such as increasing voltage measurement range and input impedance, converting to current measurement, providing line matching, etc., as follows:

a. H-P 11004A Line Matching Transformer. Provides balanced 135-ohm or 600-ohm input, 5 kc to 600 kc.

b. H-P 11005A Bridging Transformer. Allows voltage measurement on balanced lines. 20 cps to 45 kc.

c. H-P 11039A Capacitive Voltage Divider. Safely measures power-frequency voltages to 25 kilovolts. Division ratio, 1000:1. Input capacity, 15 pf \pm 1 pf.

d. H-P 11041A Capacitive Voltage Divider. Accuracy \pm 3%. Division ratio, 100:1. Input impedance, 50 megohms, resistive, shunted with 2.75 pf capacity. Maximum voltage, 1500 volts.

e. H-P 456A AC Current Probe. Allows current measurements without breaking the circuit. Sensitivity 1 mv/ma \pm 2% at 1 kc. Maximum input 1 amp rms; 2 amp peak. Output noise less than 50 μ v rms.

f. H-P 11029A-11034A Shunt Resistors. For measuring currents as small as 1 microamp full scale. Accuracy \pm 1% to 100 kc, \pm 5% to 4 mc (470A, \pm 5% to 1 mc). Maximum power dissipation, 1 watt.

SECTION II

INSTALLATION

2-1. UNPACKING AND INSPECTION.

2-2. There are no special precautions for unpacking the voltmeter. Save the shipping carton and packing materials for possible storage or reshipment. When unpacking, inspect instrument and packing materials for signs of damage in shipment. Make an operation check as directed in paragraph 2-10 to determine if performance is satisfactory. If there is any indication of damage, immediately file a claim with the transport service used or other cognizant authority.

2-3. LINE VOLTAGE REQUIREMENT.

2-4. The voltmeter is wired at the factory for use on 115-volt a-c power. This voltage may vary $\pm 10\%$ without adverse effect upon voltmeter performance. The voltmeter can be wired for use on 230-volt a-c power by reconnecting the dual primary windings on the power transformer as shown in the schematic diagram in Section V. When using 230-volt power, change from a 1-amp to a 1/2-amp slow-blow fuse. If necessary, provide an adapter for attaching the standard 115-volt plug on the voltmeter to the 230-volt outlet.

2-5. POWER LINE CONNECTION.

2-6. The three-conductor power cable on the voltmeter is terminated in a polarized three-prong male connector. The third contact is an offset round pin added to a standard two-blade connector, which grounds the instrument chassis when used with the appropriate receptacle. To connect this plug in a standard two-contact receptacle, use an adapter. The chassis ground connection is brought out of the adapter in a green pigtail lead for connection to a suitable ground.

2-7. The power plug normally supplied with the voltmeter is made of molded rubber and is an integral part of the power cable. On certain military contracts, a modification of the Model 400D, termed the H02-400D, is equipped with a removable plug having the same pin configuration but constructed of corrosion-resistant material. In all other respects the H02-400D is the same as the Model 400D and carries the same Federal Stock Number.

WARNING

The lower INPUT and OUTPUT signal terminals on the panel of the voltmeter are connected directly to the chassis of the voltmeter. Any voltage applied to the lower terminal will be shorted directly to ground. If the ground connection in the power cord is disconnected by use of an adapter, the entire voltmeter cabinet will carry whatever potential is applied to the lower terminal and may be a hazard to the operator.

2-8. INSTALLATION.

2-9. The voltmeter is a portable instrument requiring no permanent installation. The voltmeter is for bench-top operation, standing on its rubber feet with its front panel near the vertical plane. A bail is provided for raising the front of the cabinet to obtain a better viewing angle.

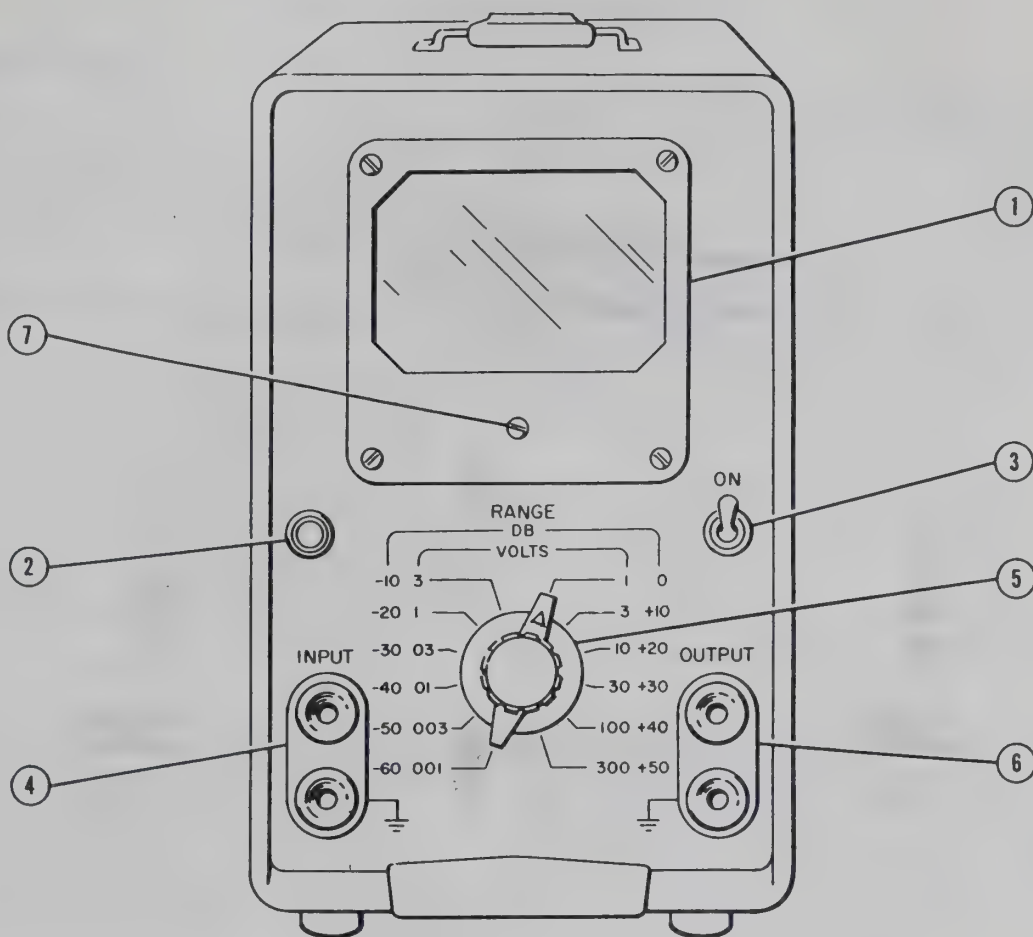
2-10. OPERATION CHECK.

2-11. The voltmeter is ready for use as received from the factory. The simple check described below can be made by incoming inspectors to determine if electrical damage was incurred in shipment. If more complete proof of instrument performance is required, the over-all performance check described in paragraph 5-22 must be used. Make a simple performance check as follows:

a. Connect voltmeter to the power line through a variable transformer. Set transformer for 115 volts, turn on and allow a five-minute warmup.

b. Measure any sine wave voltage, excepting the power line, from 0.01 to 300 volts whose exact voltage is known. Note that the lower INPUT terminal is connected to the power line ground.

c. While making the above measurement, adjust the line voltage from 103 to 127 volts. The reading on the meter must not change by more than the width of the pointer.



REFERENCE NUMBER	DESIGNATION	FUNCTION
1	Panel meter	Indicates rms volts and decibels of sine wave signals.
2	Indicator light	Indicates that voltmeter is turned on.
3	ON Power switch	Applies line power to voltmeter.
4	INPUT terminals	Receive voltage to be measured or signal to be amplified.
5	RANGE (DB-VOLTS) switch	Selects full-scale deflection sensitivity.
6	OUTPUT terminals	Supply signal level proportional to meter reading, with same waveform as applied to INPUT terminals.
7	Zero adjust screw	Meter zero adjust screw (for 400D and 400H only).

Figure 3-1. Voltmeter Front Panel, Showing Controls and Connectors

SECTION III

OPERATING INSTRUCTIONS

3-1. INSTRUMENT TURN-ON.

3-2. The voltmeter is ready for use as received from the factory and will give specified performance after a few minutes warmup. See Section II for information regarding connection to the power source and to the voltage to be measured. Controls are shown in figure 3-1.

3-3. GENERAL OPERATING INFORMATION.

3-4. **METER ZERO CHARACTERISTIC.** When the Model 400D and 400H Voltmeters are turned off, the meter pointer should rest exactly on the zero calibration mark on the meter scale. If it does not, zero-set the meter as instructed in paragraph 5-7. The meter supplied in the Model 400L Voltmeter is not provided with a mechanical meter zero adjustment. When the voltmeter is turned on with the INPUT terminals shorted, the meter pointer may deflect upscale slightly; this deflection does not affect the accuracy of a reading.

NOTE

When the voltmeter RANGE switch is set to the lowest ranges and the INPUT terminals are not terminated or shielded, noise pickup can be enough to produce up to full-scale meter deflection. This condition is normal and is caused by stray voltages in the vicinity of the instrument. For maximum accuracy on the .001-volt range, the voltage under measurement should be applied to the voltmeter through a shielded test lead.

3-5. **METER SCALES.** The two voltage scales on each of the voltmeter models are related to each other by a factor of $1:\sqrt{10}$ (10 db). In conjunction with the calibrated RANGE switch steps, this provides an intermediate range step spaced 10 db between "power of ten" ranges, which are 20 db apart. The relationship of the DECIBELS scale to the 0 to 1 VOLT scale is determined by making 0 db on the DECIBELS scale equal to the voltage required to produce 1 milliwatt in 600 ohms (0.775 volts). Thus, the DECIBELS scale reads directly in dbm (decibels referred to one milliwatt) across a 600-ohm circuit, and can be used to measure absolute level of sine wave signals. It can also be used to measure relative levels of any group of signals which have the same waveform, across any constant circuit impedance. The RANGE switch changes voltmeter sensitivity in 10-db steps accurate to within $\pm 1/8$ db. The RANGE switch position indicates the value of a full-scale meter reading.

3-6. **CONNECTIONS.** Voltmeter test leads must be provided by the user. The type of leads and probes used will depend upon the application, as listed below:

a. For connection to low-impedance signal sources, plain wire leads often are sufficient.

b. For high-impedance sources, or where noise pickup is a problem, low-capacity shielded wire must be used with a shielded, dual banana plug for connection to the voltmeter terminals.

c. If a probe is used, it should also be shielded to prevent pickup from the hand.

d. For signals above a few hundred kilocycles, the capacity of the test leads must be kept to a minimum by using very short leads, preferably unshielded. An alligator clip should be used at the test end so that connection can be made without adding the capacity of the user's hands.

3-7. **MAXIMUM INPUT VOLTAGE.** Do not apply more than 600 volts dc to the INPUT terminals. To do so exceeds the voltage rating of the input capacitor.

3-8. If an applied voltage momentarily exceeds the selected full-scale voltmeter sensitivity, a few seconds may be required for circuit recovery, but no damage will result.

3-9. **INPUT VOLTAGE WAVEFORM.** The voltmeter is calibrated to indicate the root-mean-square value of a sine wave; however, meter pointer deflection is proportional to the average value of whatever waveform is applied to the input. If the input signal waveform is not a sine wave, the reading will be in error by an amount dependent upon the amount and phase of the harmonics present, as shown in figure 3-2 below. When harmonic distortion is less than about 10%, the error which results is negligible.

INPUT VOLTAGE CHARACTERISTICS	TRUE RMS VALUE	METER INDICATION
Fundamental = 100	100	100
Fundamental +10% 2nd harmonic	100.5	100
Fundamental +20% 2nd harmonic	102	100-102
Fundamental +50% 2nd harmonic	112	100-110
Fundamental +10% 3rd harmonic	100.5	96-104
Fundamental +20% 3rd harmonic	102	94-108
Fundamental +50% 3rd harmonic	112	90-116

Note: This chart is universal in application since these errors are inherent in all average-responding type voltage-measuring instruments.

Figure 3-2. Effect of Harmonics on Voltage Measurements

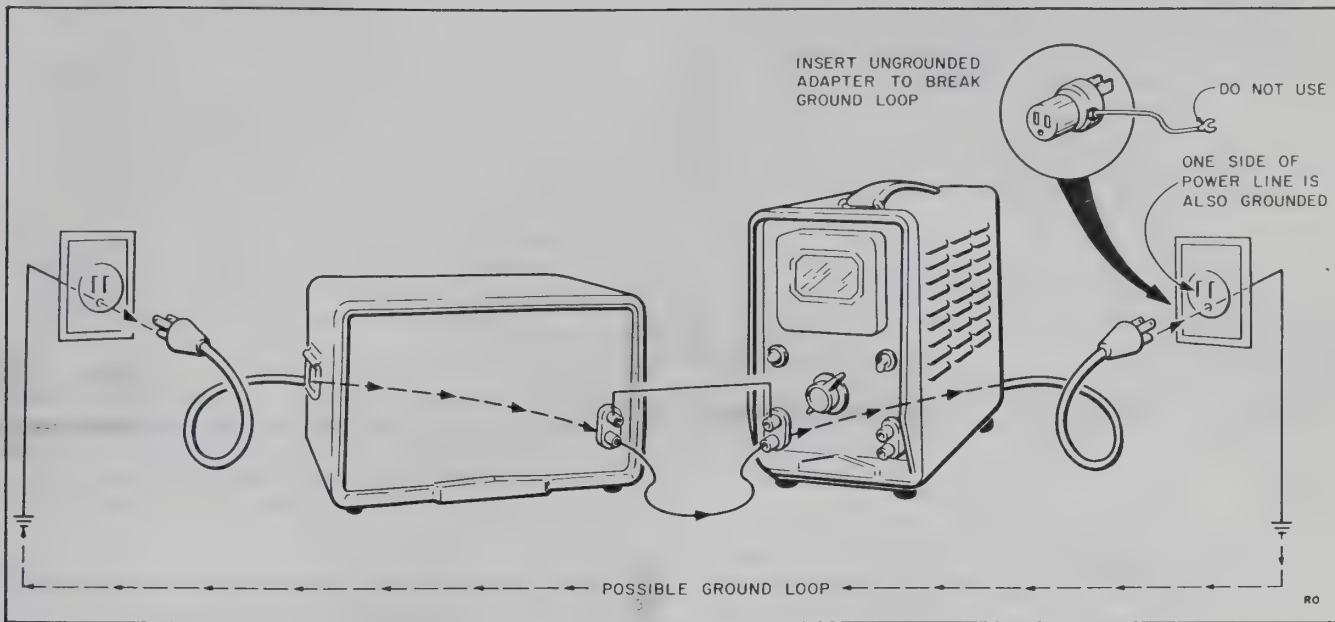


Figure 3-3. Test Setup for Avoiding Ground Loop

3-10. Since the voltmeter meter deflection is proportional to the average value of the input waveform, it is not adversely affected by moderate levels of random noise. The effect that noise has on the accuracy of the meter reading depends upon the waveform of the noise, and upon the signal-to-noise ratio. A square wave has the greatest effect, a sine wave intermediate effect, and "white" noise has the least effect on the meter reading.

3-11. If the noise signal is a 50% duty cycle square wave and the signal-to-noise ratio is 10:1 (between peak voltages), the error will be about 1% of the meter reading. If the noise signal is "white" noise and the signal-to-noise ratio 10:1, the error is negligible.

3-12. LOW-LEVEL MEASUREMENTS AND GROUND CURRENTS.

3-13. When the voltmeter is used to measure signal levels below a few millivolts, ground currents in the meter test leads can cause an error in meter reading. Such currents are created when two or more ground connections are made between the instruments of a test setup and/or between the instruments and the power line ground. Two ground connections complete an electrical circuit (ground loop) for the voltages which are generated across all instrument chassis by stray fields, particularly the fields of transformers. These ground currents can be minimized by disconnecting the ground lead in the power cord from either the voltmeter or the signal source being measured, at the power outlet as shown in figure 3-3, and by making sure that in the test setup no other ground loop is formed that can cause a ground current to flow in the voltmeter test leads. Although the resultant voltage developed across a test lead is in the order of microvolts, it is enough to cause noticeable errors in measurements of a few millivolts. The presence of ground currents can sometimes be determined by simply changing the grounds for the instruments in the

setup and watching for a change in meter reading. If changing the ground system causes a change in meter reading, ground currents are present.

3-14. MEASUREMENT OF VOLTAGE.

3-15. The meter has two VOLTS scales, 0 to 1 and 0 to 3. When the RANGE switch is set to .001, .01, .1, 1, 10, or 100 VOLTS, read the 0 to 1 scale. When the RANGE switch is set to .003, .03, .3, 3, 30, or 300 VOLTS, read the 0 to 3 scale.

CAUTION

The lower (black) signal INPUT and OUTPUT terminals and the instrument case are connected to the power system ground when the instrument is used with a standard three-terminal (grounding) receptacle. Connect only ground-potential circuits to the black INPUT and OUTPUT terminals.

3-16. Operate the instrument as follows:

- Connect the voltmeter to the a-c power source.
- Turn the Power switch ON and allow a warmup period of approximately five minutes.
- Disconnect any external equipment from the OUTPUT terminals.
- Set the RANGE switch to the VOLTS range which will read the voltage to be measured at mid-scale or above. If in doubt, select a higher VOLTS range.
- Connect the voltage to be measured to the INPUT terminals.

CAUTION

AVOID A SHORT CIRCUIT ACROSS THE POWER LINE! To measure power line voltage, first connect only the upper (red) INPUT terminal to each side of the power line, in turn, leaving it connected to the side that causes meter indication. Then connect the lower (black) INPUT terminal (grounded internally) to the other side of the line. If this procedure is not followed, the power line may be short-circuited through the grounded INPUT terminal of the voltmeter.

f. Read the meter indication on the appropriate VOLTS scale, in accordance with the full-scale value indicated on the RANGE switch. Evaluate the reading in terms of the full-scale value indicated on the RANGE switch. Study the following examples:

Example 1

When the RANGE switch is in the .1 VOLTS range, read the 0 to 1 VOLTS scale. If the meter indicates .64 on that scale, the voltage being measured is:

$$.64 \text{ (meter indication)} \times \frac{.1 \left[\begin{array}{c} \text{switch-selected} \\ \text{voltage range} \end{array} \right]}{1 \text{ (full-scale value)}} = .064 \text{ volt}$$

Example 2

When the RANGE switch is in the 30 VOLTS range, read the 0 to 3 VOLTS scale. If the meter indicates 1.6 on that scale, the voltage being measured is:

$$1.6 \text{ (meter indication)} \times \frac{30 \left[\begin{array}{c} \text{switch-selected} \\ \text{voltage range} \end{array} \right]}{3 \text{ (full-scale value)}} = 16 \text{ volts}$$

3-17. MEASUREMENT OF DECIBELS.

3-18. The DECIBELS meter scale is provided for measuring dbm directly across 600 ohms and for measuring db ratio for comparison purposes when each measurement is made across the same circuit impedance. To measure signal level directly in dbm (0 dbm equals 1 milliwatt into 600 ohms) proceed as follows:

- a. Connect the voltmeter to the a-c power source.
- b. Turn the Power switch ON and allow a warmup period of approximately five minutes.
- c. Disconnect any external equipment from the OUTPUT terminals.
- d. Set the RANGE switch to the DB range which will give an upscale reading of the signal to be measured. If in doubt, select a higher-level scale.
- e. Connect the voltage to be measured to the INPUT terminals.

f. Note the meter indication on the DECIBELS scale (-12 to +2 db). The signal level is the algebraic sum of the meter indication and the db value indicated by the RANGE selector. Study the following examples:

Example 1

If the indication on the DECIBELS scale is +2 and the RANGE switch is in the +20 DB position, the level is +22 dbm.

Example 2

If the indication on the DECIBELS scale is +1.5 and the RANGE switch is in the -40 DB position, the level is -38.5 dbm.

3-19. To measure db across impedances other than 600 ohms, follow the above procedure and evaluate the results as follows:

NOTE

Since the measurement is made across other than 600 ohms, the level obtained in step f is in db, but not in dbm.

a. To obtain the difference in db between measurements made across equal impedances, algebraically subtract the levels being compared.

b. To obtain the reading of a single measurement in dbm, note the impedance across which the measurement is made and refer to the Impedance Correction Graph, described in paragraph 3-20.

c. To obtain the difference in dbm between measurements made across different impedances, convert each measurement to dbm using the Impedance Correction Graph described in paragraph 3-20. Then algebraically subtract the dbm levels being compared.

3-20. IMPEDANCE CORRECTION GRAPH.

3-21. As the voltmeter DECIBELS scale is calibrated to indicate dbm for measurements made across 600-ohm circuits, a correction factor must be used when measurements are made across circuit impedances other than 600 ohms, if absolute dbm levels are desired. The correction factor is not necessary in measuring relative db levels (not dbm) across the same impedance, but it is required for comparison of db levels measured across different impedances. The Impedance Correction Graph in figure 3-4 gives the correction factor for conversion of the meter reading to dbm when the impedance of the circuit under test is known. To use the graph, read the conversion factor corresponding to the test circuit impedance and add it to the meter reading determined by the method of paragraph 3-17. Observe the algebraic sign of the correction factor in making the algebraic addition. Use the following examples:

Example 1

If the measurement is made across 90 ohms, the indication on the DECIBELS scale is +2, and the RANGE switch is at the +30 DB position, the level in dbm is obtained as follows:

+ 2 (meter indication)	
+30 (RANGE switch position)	
+32 (sum)	
+ 8 (correction factor from the Impedance	
+40 dbm	Correction Graph)

Example 2

For the same conditions as given above, except that the measurement is made across an impedance of 60,000 ohms, the level in dbm is obtained as follows:

+ 2 (meter indication)	
+30 (RANGE switch position)	
+32 (sum)	
-20 (Correction factor from the Impedance	
+12 dbm	Correction Graph)

3-22. USE OF VOLTMETER AMPLIFIER.

3-23. The amplifier in the voltmeter may be used for amplifying weak signals. With full-scale meter deflection, the open-circuit output of the amplifier is approximately 0.15 volt rms regardless of the RANGE switch position. The impedance looking into the OUTPUT terminals is approximately 50 ohms. The frequency

response and calibration of the voltmeter may be affected by the impedance of a load applied to the OUTPUT terminals. To check the effect of the applied load: observe the meter reading obtained with no load connected to the OUTPUT terminals and then note any shift of reading when the external circuit is connected to the OUTPUT terminals. If the shift is negligible, the measurement is not being affected appreciably by the load. Whenever the input signal is changed, i.e., a different frequency or band of frequencies is applied, repeat the quick check described above.

3-24. Maximum gain from the amplifier is obtainable only on the lowest (.001 volts) range, since output level is the same for all bands. This is due to the 10-db amplification loss per step inserted by the RANGE switch as it is turned clockwise. Amplification may also be obtained on the .003, .01, .03, and 1 volt ranges.

3-25. When the voltmeter is used as an amplifier, select a range which gives a meter deflection near full scale. Off-scale signals more than twice the value of the position of the RANGE switch will cause severe distortion.

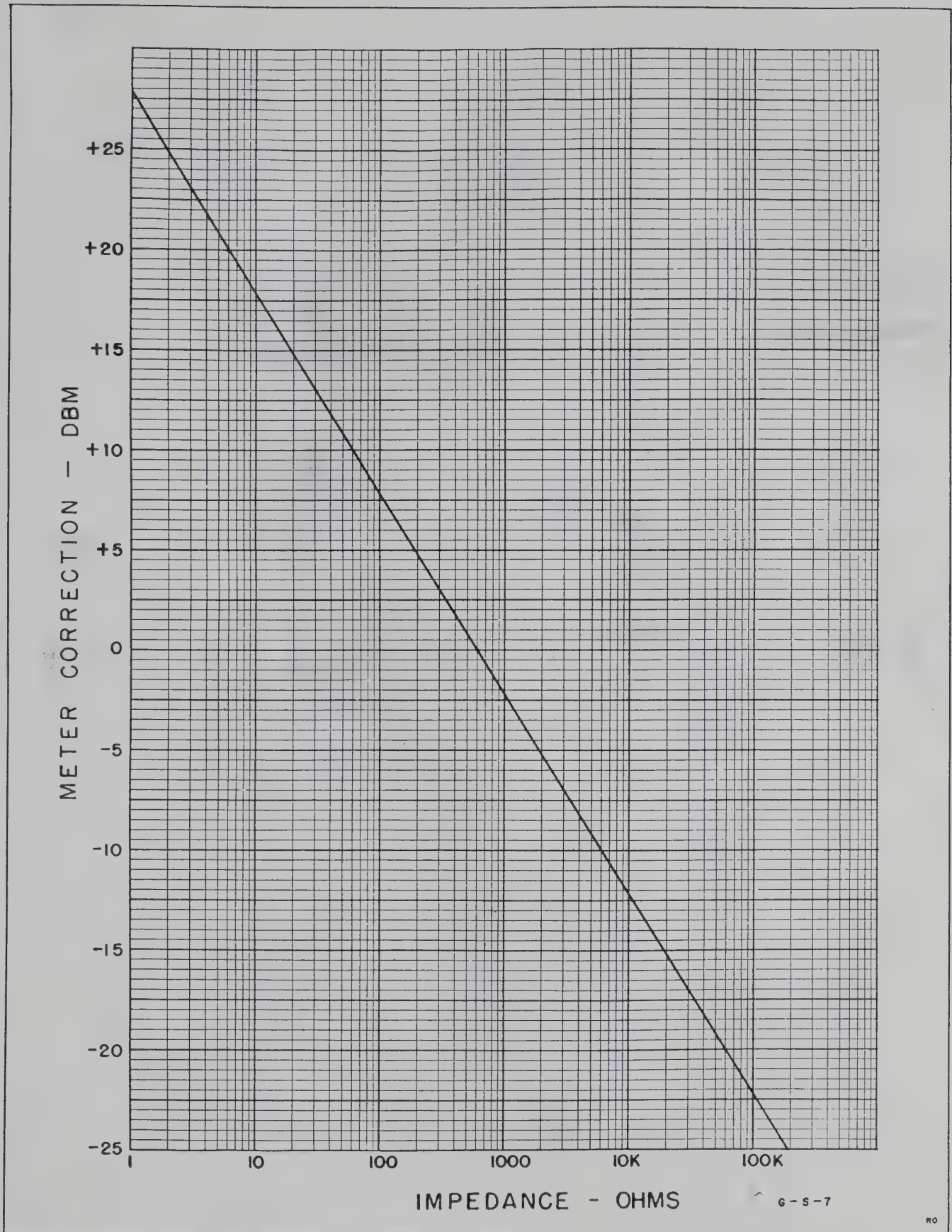


Figure 3-4. Impedance Correction Graph

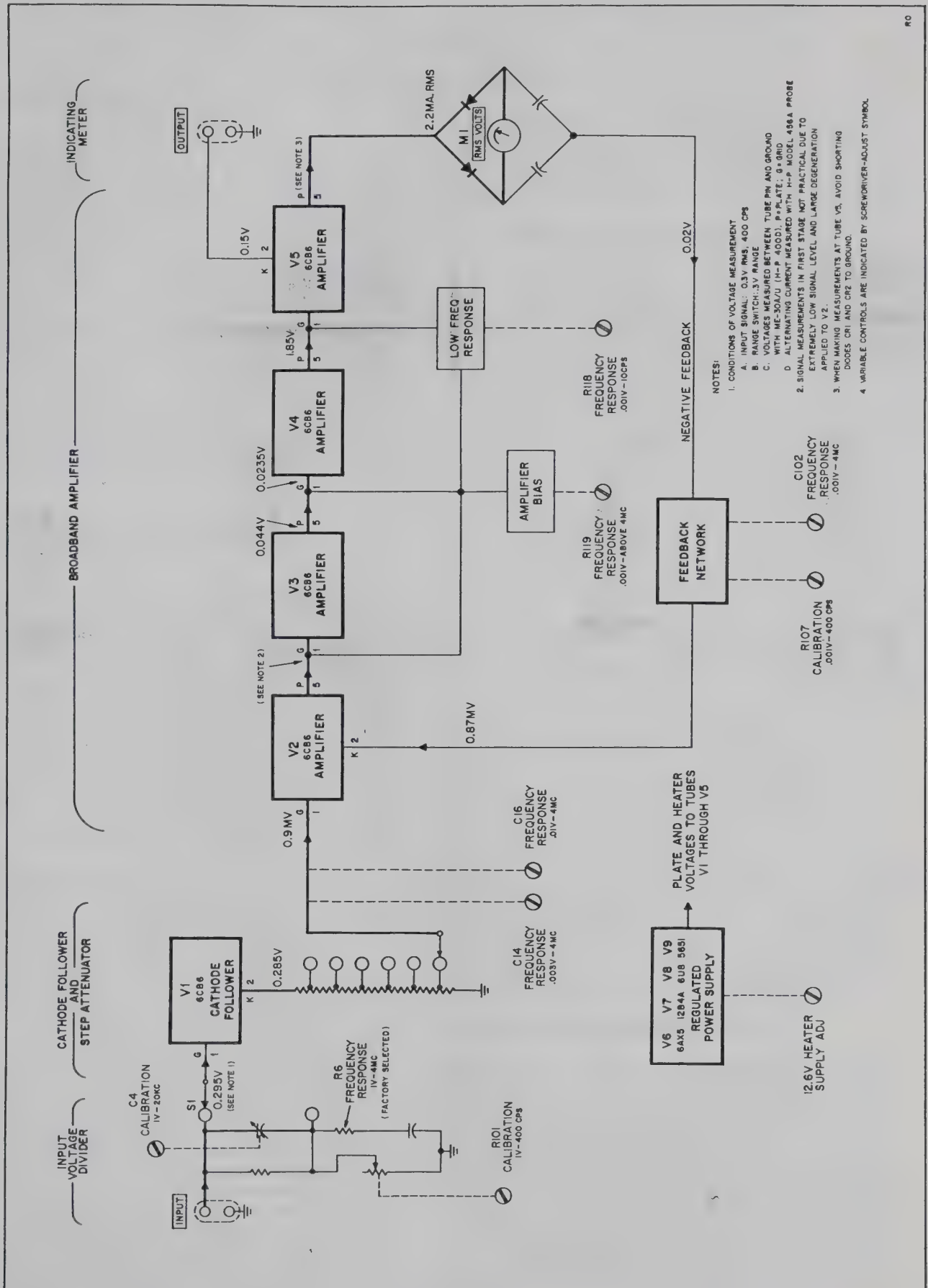


Figure 4-1. Voltmeter Block Diagram

SECTION IV

CIRCUIT DESCRIPTION

4-1. BLOCK DIAGRAM.

4-2. The electrical circuits of the voltmeter are shown in the block diagram in figure 4-1; they consist of an input voltage divider controlled by the RANGE switch, a cathode follower input tube, a precision step attenuator controlled by the RANGE switch, a broadband amplifier, an indicating meter, and a regulated power supply. The voltage applied to the INPUT terminals for measurement is divided by 1000 before application to the input cathode follower when the RANGE switch is set to the 1-volt range and higher; the input voltage is applied directly to the cathode follower on the lower ranges. The voltage from the cathode follower is divided in the precision attenuator to be less than 1 millivolt for application to the voltmeter amplifier. The output of the amplifier is rectified in a full-wave bridge rectifier with a d-c milliammeter across its midpoints. The resultant direct current through the meter is directly proportional to the input voltage.

4-3. INPUT VOLTAGE DIVIDER AND STEP ATTENUATOR.

4-4. The input voltage divider limits the signal level applied to the input cathode follower to less than 0.3 volt rms when voltages above this level are measured with the RANGE switch set at the 1-volt range or above. The divider consists of a resistive branch with one element made adjustable to obtain exact 1000:1 division at middle frequencies and a parallel capacitive branch with one element made adjustable to maintain exact 1000:1 division to beyond 4 megacycles. The input impedance of the voltmeter is established by this divider and is the same for all positions of the RANGE switch. On the six low-voltage positions of the RANGE switch, the input divider provides no attenuation of the input voltage. (See figure 5-10 for the complete schematic.)

4-5. The step attenuator in the cathode circuit of the input cathode follower reduces the voltage to be measured to 1 millivolt or less for application to the voltmeter amplifier. Each step of the attenuator lowers the signal level by exactly 10 db ($1:\sqrt{10}$). The attenuator consists of six precision wirewound resistors which are selected to very high accuracy and carefully mounted on a 12-position rotary switch. The RANGE switch rotor has two contactors (see figures 5-9 and 5-10); the first contacts each resistor in turn while the input divider is in the non-attenuating position; the second rotor finger repeats these contacts while the input attenuator is in the attenuating position. On the .001-volt range a fixed capacitor (C15) is automatically connected to provide flat frequency response beyond 4 megacycles. In the .003- and the .01-volt ranges, separate adjustable capacitors (C14, C16) are automatically connected to the attenuator to permit setting the frequency response at 4 megacycles. C14 and C16 are also connected to the attenuator on the 3- and 10-volt ranges. Fixed capacitor C106 (permanently connected) flattens frequency response on the .03- and 30-volt ranges.

4-6. Cathode follower V1 provides a constant, high input impedance to the input voltage divider and INPUT terminals of the voltmeter and provides a relatively low impedance in its cathode circuit to drive the step attenuator. The voltage gain factor across V1 is 0.95.

4-7. BROADBAND VOLTMETER AMPLIFIER.

4-8. Amplification of the signal voltage is provided by a four-stage stabilized amplifier consisting of tubes V2 through V5 and associated circuits. The amplifier provides between 55- and 60-db gain with about 55 db of negative feedback at mid-frequencies. The feedback signal is taken from the plate of the output amplifier (V5) through the meter rectifiers and gain-adjusting circuit to the cathode of the input amplifier (V2). Variable resistor R107 in the feedback network adjusts the negative feedback level to set the basic gain of the amplifier at mid-frequencies, while adjustable capacitor C102 permits setting amplifier gain at 4 megacycles. Variable resistor R118 in the coupling circuit between V4 and V5 permits adjusting the gain of the amplifier at 10 cycles per second by controlling the phase shift of low-frequency signals between these two stages (increasing phase shift decreases degeneration and increases gain).

4-9. Variable resistor R119 in the grid return path for V3, V4, and V5 adjusts the total transconductance of these tubes in order to restrict the maximum gain-bandwidth product of the amplifier. The gain-bandwidth product must be restricted to give a smooth frequency response rolloff above 4 megacycles and to prevent possible unstable operation at frequencies far above 4 megacycles when tubes having unusually high transconductance are used (tube transconductance tolerances during manufacture permit wide variations in new tubes; the adjustment permits the use of such tubes). The plate voltage from V5 is rectified by the meter rectifiers and drives the feedback network. The cathode voltage of V5 is fed to the meter OUTPUT terminals for monitoring purposes. The current through V5, and thus the signal voltage at the cathode, is affected by the loading of the meter rectifiers. For signal levels causing third-scale or more meter deflection, this distortion consists of a very small irregularity near 0 volts on the waveform as each diode begins conduction.

4-10. INDICATING METER CIRCUIT.

4-11. The meter rectifier circuit consists of two silicon diodes and two capacitors connected as a bridge with the indicating meter across the mid-points as shown in figure 4-2. The diodes provide full-wave rectification of the signal current for operating the meter. Electron flow through the meter is supplied in the following manner (see figure 4-2). During the positive-going half cycle of plate voltage on V5, rectifier CR1 conducts electrons from both C32 and C33 back to the B+ buss. The portion of electrons from C33 flows through the meter on the way to B+. At this point in the cycle, both C32 and C33 are charged to the potential of B+ less some small drop in R51 and R52.

4-12. During the negative-going half cycle of the plate voltage of V5, rectifier CR2 conducts electrons back to both C32 and C33 from the plate of V5. That portion of electrons going back to C32 flows through the meter on the way (in the same direction that the electrons flowed in the first, positive, half cycle). At this point in the cycle, both C32 and C33 are discharged. The pulsating current through the meter is smoothed by C34 to prevent meter pointer vibration when measuring low-frequency signals. The current is proportional to the arithmetic average value of the waveform amplitude of the signal. Meter calibration in rms volts is based on the mathematical ratio between the average and rms values of true sine wave current.

4-13. In addition, the bridge serves as a segment of a voltage divider (in series with L11 and R108) connected across the output of the amplifier. The negative feedback voltage fed to the input of the amplifier is obtained across L11 and R108. The alternating charge and discharge of C32 and C33 produce at their junction with L11 an alternating current of the same phase and waveform as that at the plate of V5. This phase is negative with respect to the input signal applied to the first stage of the amplifier (V2), and drives the negative feedback network.

4-14. POWER SUPPLY.

4-15. The power supply consists of tubes V6 through V9 and the associated circuits, as shown in the complete

schematic diagram, figure 5-10. The power supply furnishes regulated +250V d-c voltage for the grid and plate bias circuits of tubes V1 through V5, unregulated 12.6V d-c voltage for the heater supply of tubes V1 through V4, and 6.3V a-c voltage for the heater supply of tubes V5 through V8. The power supply is designed to operate from either a 115-volt ($\pm 10\%$) or a 230-volt ($\pm 10\%$) a-c power source of 50 to 1000 cps. The primary winding of power transformer T1 is arranged in two sections, which can be strapped either in parallel or in series, to permit operation on 115V or 230V, respectively.

4-16. The output of rectifier V6 is applied to the voltage regulator circuit consisting of V7 through V9 which supplies a constant, +250 volts dc to the stabilized amplifier circuit of the voltmeter. Tube V7 is the series regulator tube, and V9 provides a fixed reference voltage drop, with which the output voltage is compared in amplifier V8B. V8A is a cathode follower which couples the reference voltage from V9 to V8B without loading V9. The regulated output voltage is applied to the control grid of V8B, while the reference voltage is applied to its cathode. The difference between the control grid and cathode voltages controls the operating point of V8B and thus its plate voltage, which in turn supplies the grid voltage for regulator V7. Any change in the regulated output of V7 produces a correcting change in the grid bias of V7 through the action of V8B, thus maintaining an essentially constant output voltage despite changes in line voltage or load on the supply. The gain of V8B is high enough to keep the output at the V7 cathode regulated

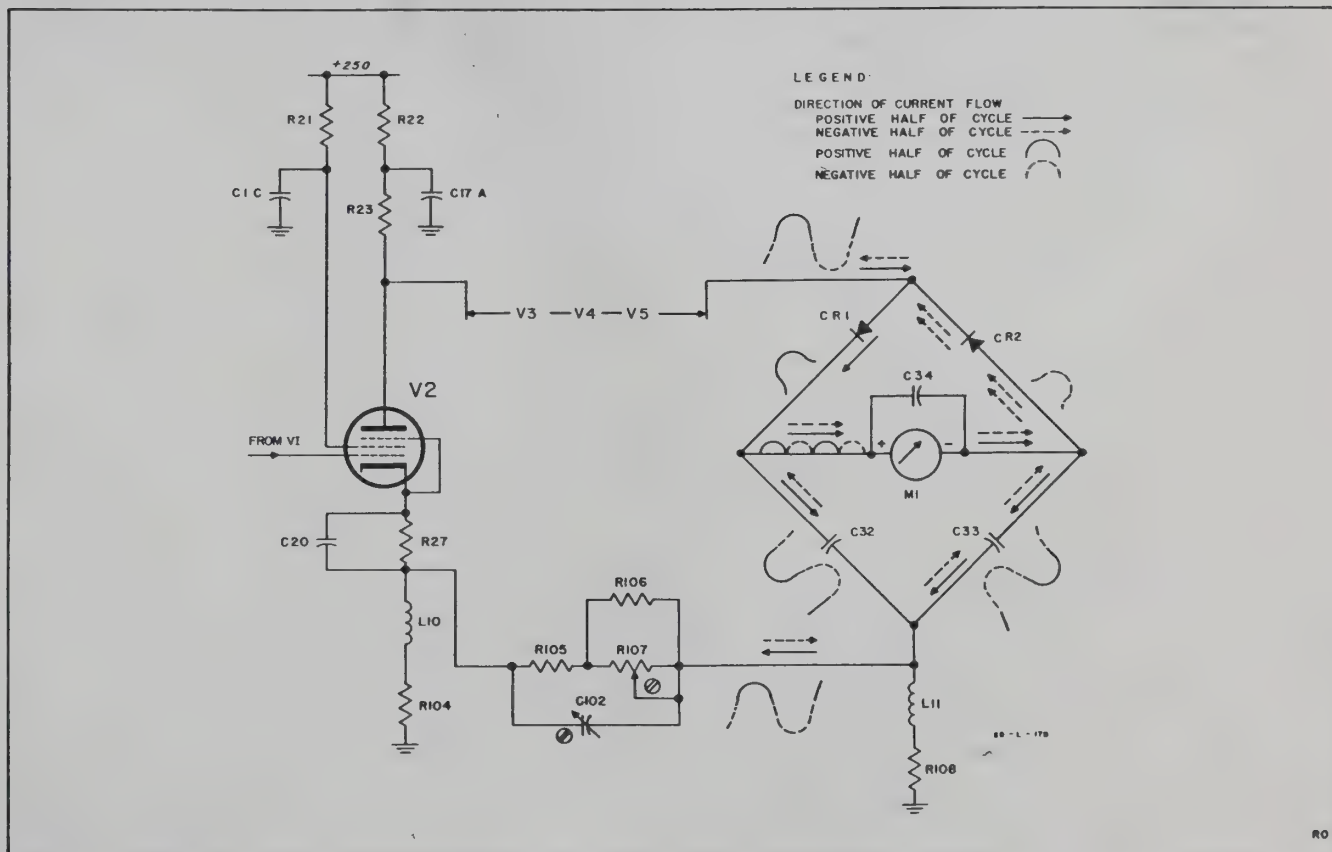


Figure 4-2. Simplified Schematic of Meter Bridge Circuit

to within ± 1 volt dc as the V7 plate voltage is varied $\pm 10\%$, with about 60 ma of load current. The response of the regulating circuits is fast enough to reduce ripple in the output voltage to less than 1 millivolt, supplementing the filtering action of C30. C36 couples the ripple component in the regulated output directly to V8B to avoid attenuation in R62. R57 shunts a small portion of the load current around V7 to prevent excessive V7 plate dissipation at high line voltages. R63 and C35 constitute a low-pass filter which prevents noise generated in V9 from reaching V8B.

4-17. The heater supply for the voltmeter tubes is divided into two sections. One section supplies d-c voltage for the tubes in the input cathode follower and

the amplifier. The other section supplies a-c voltage for the tubes in the power supply. The voltage required for the heaters of tubes V1 through V4 is obtained from 6.3V and 7.3V secondary windings of transformer T1, which are series connected. The voltage developed across the two series-connected windings is rectified by full-wave rectifier CR3, reduced to 12.6 volts by R66 and R68 in parallel, and applied to the series-parallel-connected heaters of V1 through V4, as shown in figure 5-10. The series-parallel connection of the four heaters establishes a voltage of 6.3V for each. The heater of V5 receives 6.3V ac from one of the windings which drives CR3. The heaters of V6, V7, and V8 receive 6.3V ac from a separate 6.3V secondary winding on T1.

SECTION V

MAINTENANCE

5-1. SCOPE.

5-2. This section contains complete instructions for repairing and calibrating the voltmeter. This material is covered in the following groups of paragraphs:

Lead Paragraph	Topic
5-3.	Precautions
5-5.	Test Equipment Required
5-7.	Meter Zero Adjustment
5-9.	Cabinet Removal
5-10.	Tube Replacement
5-13.	Replacement of Special Parts
5-17.	Trouble Shooting
5-20.	Testing the Power Supply
5-22.	Testing Voltmeter Performance
5-24.	Calibration and Frequency Response Adjustments

5-3. PRECAUTIONS.

5-4. Observe the following precautions:

a. Make no adjustments and replace no parts in the voltmeter except as described in one of the following

procedures. If an adjustment or replacement of parts is made without following instructions or understanding the effects, further trouble shooting may be complicated.

b. Do not remove tubes when the voltmeter is turned on. Before replacing tubes refer to paragraph 5-10.

5-5. TEST EQUIPMENT REQUIRED.

5-6. The test equipment required for complete testing of the voltmeter is listed in figure 5-1. Equivalent instruments may be substituted for those listed.

5-7. METER ZERO ADJUSTMENT.

5-8. The meter is properly zero-set when its pointer rests over the zero calibration mark on the meter scale when the instrument is 1) at normal operating temperature, 2) in its normal operating position, and 3) turned off. Adjust the zero-set if necessary, as follows:

a. Allow the voltmeter to operate for 20 minutes so that the meter movement will reach normal operating temperature.

b. Turn the voltmeter off and allow one minute for all capacitors to discharge.

INSTRUMENT TYPE	REQUIRED CHARACTERISTICS	USE	DESIGNATION
Electronic Multimeter	0 to 300 a-c and d-c volts; accuracy of $\pm 3\%$ or better; input impedance 100 megohms.	Voltage and resistance measurement.	ME-26B/U or H-P 410B
Oscillator	10 cps to 300 kc; 3 volts output into 50-ohm load.	Signal source for testing and calibration	H-P 200S
Voltmeter Calibrator (Precision Voltage Source)	400-cps output voltage; 0.001 to 300 volts in 10-db steps $\pm 0.2\%$; 0.1 to 1.0 volt in 0.1 volt steps $\pm 0.2\%$.	Calibrating voltmeter at mid-frequencies.	H-P 738BR
Frequency Response Test Set	300-kc to 4-mc range; 3 volts output into 50-ohm load; 10-db steps, 0 to 70 db.	Calibrating voltmeter frequency response.	H-P 739A
Oscilloscope or AC Voltmeter	10-cps to 4-mc range.	Trouble shooting by signal tracing.	H-P 160B or H-P 400D
Variable Transformer	Adjust line voltage between 103 and 127V ac with 1-amp load.	Checking voltmeter operation with varying line voltage.	CN-16/U or Ohmite VT2
D-C Current Test Set (Milliammeter)	Clip-on type measurement; current range up to 100 ma.	Checking load on power supply.	H-P 428B

Figure 5-1. Test Equipment Required

c. Rotate mechanical zero-adjustment screw clockwise until meter pointer is to the left of zero and moving upscale toward zero.

d. Continue to rotate adjustment screw clockwise; stop when pointer is exactly on zero. If pointer overshoots zero, repeat steps c and d.

e. When pointer is exactly on zero, rotate adjustment screw approximately 15 degrees counterclockwise. This is enough to free the zero adjustment screw from the meter suspension. If pointer moves during this step, because the adjustment screw is turned too far counterclockwise, repeat the procedure of steps c through e.

5-9. CABINET REMOVAL.

a. Remove the two cabinet retaining screws at the rear of the instrument.

b. Push the instrument chassis forward out of the cabinet. The bezel ring remains attached to the front panel.

c. When replacing cabinet, pull power cable through opening at rear of cabinet. Be sure power cable is not caught between chassis and cabinet. Replace retaining screws.

5-10. TUBE REPLACEMENT.



Do not remove tubes from the voltmeter when power is applied. To do so may damage the voltmeter.

5-11. In many cases instrument malfunction can be corrected by replacing a weak or defective tube. Check tubes by substitution while following the voltmeter

performance check procedure in paragraph 5-22. Results obtained through the use of a "tube checker" can be misleading. Before removing the tubes from the instrument, mark the original tubes so they can be returned to the same socket if they are not defective. Replace only those tubes proven to be defective.

5-12. Figure 5-2 lists each tube in the voltmeter with its function and the check or adjustment required if the tube is replaced.

5-13. REPLACEMENT OF SPECIAL PARTS.

5-14. PRECISION RESISTORS AND INDUCTORS. Several parts used in the voltmeter have closer tolerances than those used in most test equipment. Resistors R104, R105, R108, and R111 through R116 are precision components. If these resistors require replacement, use the same value and type as the original, as shown in the parts breakdown. If different values are used or component positions are moved, the calibration of the voltmeter may be inaccurate or the frequency response may be altered. The inductance of L10 and L11 affects the frequency response of the voltmeter. Do not alter the shape or position of these coils. Install replacement components in the same positions the original components occupied, as nearly as possible.

5-15. DIODE RECTIFIERS. Special high-performance silicon diodes selected by the Hewlett-Packard Co. are used for CR1 and CR2. When replacing the silicon diodes, be careful in soldering; heat can damage them. Place a heat sink (such as a long-nose pliers) on each diode lead close to the diode body to conduct the heat away. If CR1 and CR2 are replaced, the voltmeter calibration and frequency response must be checked as described in paragraph 5-22.

5-16. RANGE SWITCH. Because of the critical construction and wiring of switch S1, it is not practical to attempt a major repair on the switch. When mechanical failure occurs in switch S1, replace the complete

CIRCUIT REF.	TYPE	FUNCTION	CHECK OR ADJUSTMENT
V1	6CB6*	Cathode Follower	Calibration and frequency response (para. 5-22)
V2	6CB6	1st Amplifier	
V3	6CB6	2nd Amplifier	
V4	6CB6	3rd Amplifier	
V5	6CB6	4th Amplifier	
V6	6AX5	High Voltage Rectifier	Test of the power supply (para. 5-20)
V7	12B4A	Series Regulator	
V8	6U8	Control Tube	
V9	5651	Reference Tube	
* Note that V1 must be replaced by a 6CB6, aged and selected for low noise and microphonics (hp Part No. 5080-0621).			

Figure 5-2. Adjustments Required When Tubes Are Replaced

switch assembly. Use the following procedure. (Locate parts by referring to figures 5-3 and 5-4; RANGE switch connections are shown in figure 5-9.)

- a. Remove voltmeter cabinet. (See paragraph 5-9.)
- b. Loosen setscrews in RANGE switch knob and remove knob.
- c. Disconnect capacitor C104 from switch S1.
- d. Disconnect white leads from capacitors C14 and C16. Label each lead with a tag.
- e. Remove the two screws and one nut which retain the switch shield plate.
- f. Disconnect white leads from switch contacts. Tag each lead to permit easy connection to the new switch.
- g. Disconnect the heavy dark-green switch lead, the heavy light-green switch lead, and the heavy black switch lead at terminal strips. Tag each lead.

NOTE

The input shield must be removed for access to the terminal board connection of the dark-green lead.

- h. Remove the nut which holds the switch bushing to the front panel.
- i. Remove RANGE switch assembly.
- j. The sequence for installing the replacement RANGE switch assembly is the reverse of the removal procedure.
- k. After replacement of switch S1, check the calibration and frequency response of the voltmeter and make necessary adjustments.

5-17. TROUBLE SHOOTING.

5-18. The first step in trouble shooting is to learn the nature of the symptoms of the malfunction with as much detail as possible. Inspect the test setup being used when symptoms of malfunction were observed, to be sure that the source of trouble is not external to the voltmeter. Then remove the voltmeter cabinet as directed in paragraph 5-9 and inspect the circuits of the voltmeter, looking for signs of overheating, deterioration, and physical damage or tampering. Check the fuse. If the fuse is blown, try another fuse to see if it blows; if it does, measure the d-c resistance of filter capacitors C1, C17, C30, C39, rectifier CR3, and the windings of transformer T1 to locate the short circuit without applying power to the voltmeter.

5-19. If the voltmeter can be turned on safely (without the fuse blowing), measure the line voltage applied to T1 and the voltmeter power supply output voltages (see paragraph 5-20). Check the tubes of the power supply if the regulated voltage is not the proper value or is unstable. Use the procedures of figure 5-5 and the tests described in paragraph 5-22 to learn the full nature of the trouble symptom. Watch for marginal

operation by operating the voltmeter at 103 and 127 line volts while making tests. Check the tubes in the voltmeter amplifier. Measure the tube element voltages at the tube sockets and compare readings with the values shown in the voltage and resistance diagram in figure 5-8. Apply a test signal to the input and measure the voltage of the test signal while tracing it through each coupling network and each stage of amplification. Compare readings with those shown in the block diagram, figure 4-1. In figure 4-1, an a-c current probe, H-P Model 456A, is recommended for the measurement of a-c current in the meter circuit without breaking any leads. If this current probe is not available, avoid measurement of the a-c current. Check meter indications as directed in paragraph 5-22 instead. An oscilloscope may be used for observing test signal waveshape and measuring amplitude, if desired.

5-20. TESTING THE POWER SUPPLY.

5-21. The regulated power supply produces a constant +250 vdc to operate all the tubes in the amplifier section. The stability of the voltmeter depends directly upon the stability of the +250 volts from the supply. When the supply is operating satisfactorily, the +250 volt output remains constant and the ripple level on it remains less than about 1 millivolt for line voltages between 103 and 127 volts. Weak tubes (V6, V7, and V8) are the usual causes of instability. An unstable regulator tube is indicated by excessive line frequency ripple and varying output voltage as the line voltage is changed. Marginal operation is indicated if a trouble symptom appears only when a low or high line voltage is applied. To test the complete power supply proceed as follows:

- a. Connect the voltmeter to an adjustable line transformer so the applied line voltage can be varied between 103 and 127 volts. Set line voltage to 115 volts, turn on the voltmeter, and allow a five-minute warmup period.

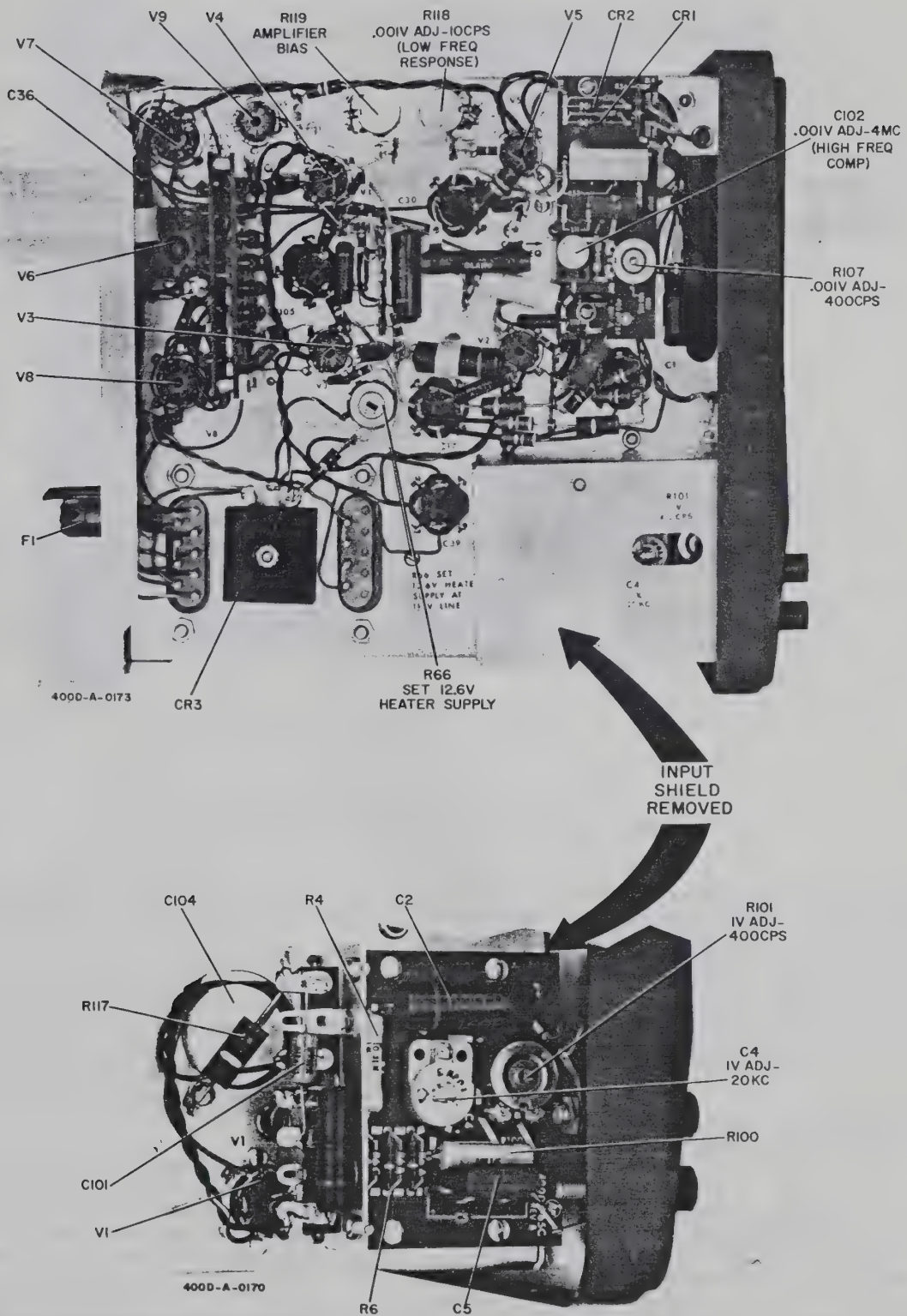
- b. Measure the d-c voltage between V6 (pin 8) and ground. Normal value is 410 ± 10 volts with exactly 115 volt power line input. Lower line voltage 10% to 103 volts for 2 minutes. If the d-c voltage slowly drops below 360 volts, replace V6.

- c. Measure the d-c voltage between V7 (pin 1) and ground with line voltage adjusted to 115 volts. Correct value is 250 ± 5 volts.

- d. Vary line voltage from 103 to 127 volts. The d-c voltage observed in step c must not change more than ± 1 volt. For wrong voltage and/or poor regulation, replace V7, V8 or V9.

- e. Measure the a-c voltage between V7 (pin 1) and ground. Ripple voltage must be less than 3 mv for any line voltage (103 to 127 volts). High ripple voltage is caused by defective V8, V7, V6 or V9. Replace in this order.

- f. Measure the direct current in the lead from V7 (pin 1) which must be less than 60 milliamperes. If the current is much too high, the regulator circuit will not function properly. Excessive current indicates



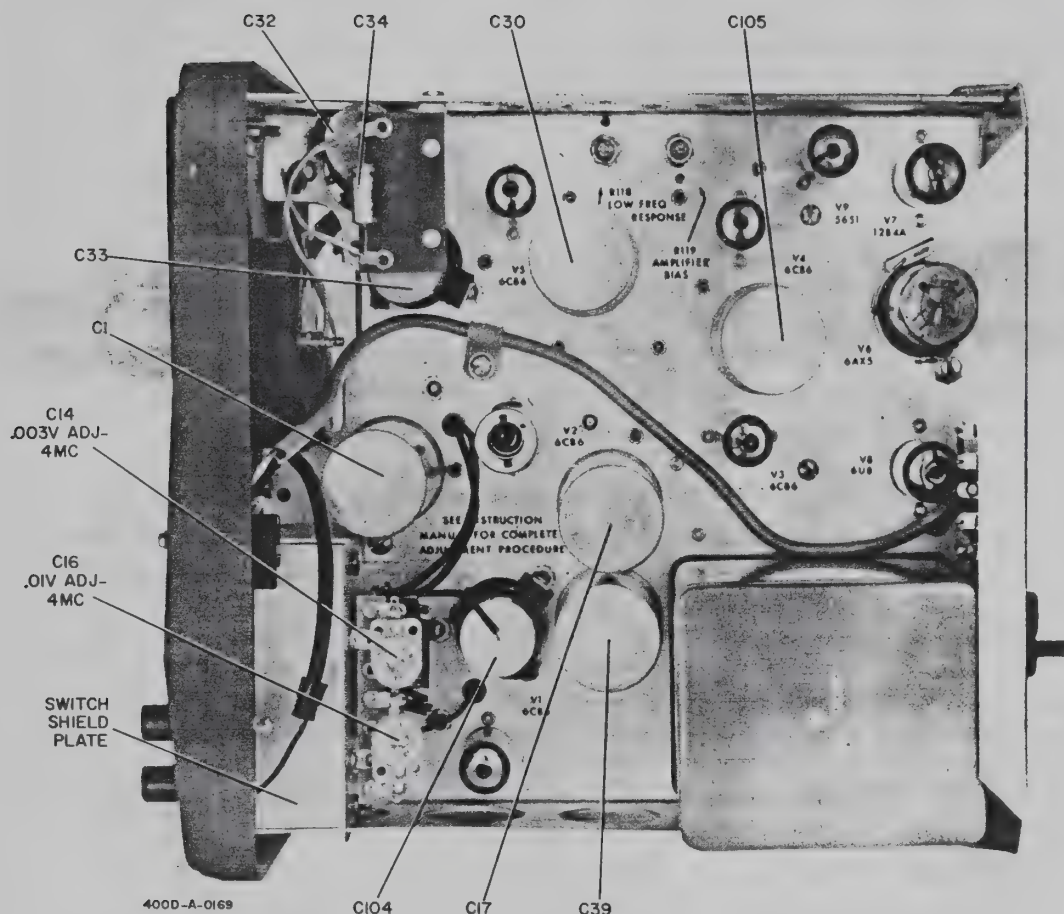


Figure 5-4. Right Side View of Voltmeter Chassis

a short circuit or partial short in the circuits of the voltmeter amplifier section. A clip-on type milliammeter should be used for this measurement.

g. If the output voltage is stable but is incorrect, measure the resistance of R62 and R64. The ratio of these two resistors determines what the output voltage will be. If the value of one of these resistors is incorrect and produces the wrong output voltage, replace it with a resistor which provides the correct output voltage.

h. Measure the d-c voltage across C39A which must be 12.6 volts with a line voltage of 115 volts. If necessary, adjust R66 to obtain 12.6 volts. If the voltage cannot be set to 12.6 volts, check the a-c voltage from the associated transformer windings; also check CR3 and C39.

5-22. TESTING VOLTMETER PERFORMANCE.

5-23. The following test procedure checks the accuracy and stability of the voltmeter at low and high frequencies

and with low and high line voltages. It can be used for comprehensive incoming inspection, for proof of performance, and for trouble shooting. If the readings are within specifications during these tests, the voltmeter is operating properly. This test is made without removing the cabinet. Instruments used to test the accuracy of the voltmeter (see paragraph 5-5) must be known to have sufficient accuracy to make valid measurements. Proceed as follows:

a. Connect the voltmeter as shown in figure 5-6. (This setup measures calibration accuracy at mid-frequencies.)

b. Set the line voltage to 115 volts, turn the voltmeter on and allow a 30-minute warmup period.

c. Check the instrument meter zero setting as instructed in paragraph 5-7.

d. Connect the voltmeter to the voltmeter calibrator; set voltmeter RANGE switch to .001, and set voltmeter calibrator VOLTAGE SELECTOR switch to provide 0 volts output.

TROUBLE	PROBABLE CAUSE	REMEDY
1. Power indicator lamp does not light.	<ul style="list-style-type: none"> a. Fuse F1 burned out. b. Power indicator lamp DS1 defective. c. Defective a-c power cable. d. Power switch S2 defective. e. Transformer T1 primary winding terminals incorrectly connected. 	<ul style="list-style-type: none"> a. Replace fuse F1. If replaced fuse blows, check items 2 and 3 below. b. Replace power indicator lamp DS1. c. Repair or replace power cable. d. Replace Power switch S2. e. Check connections of transformer T1 primary winding; rewire if necessary.
2. Fuse F1 blows immediately when Power switch S2 is operated to ON.	<ul style="list-style-type: none"> a. Tube V6 shorted. b. Rectifier CR3 defective. c. Short circuit in transformer T1 or in circuit wiring. 	<ul style="list-style-type: none"> a. Replace rectifier tube V6. b. Replace heater rectifier CR3. c. Remove all tubes, and check transformer windings. Replace transformer T1 if defective. Check for short circuit.
3. Fuse F1 blows after Power switch S2 has been operated to ON and tube heaters have warmed up.	Short in power supply circuit.	Check for short circuit at cathodes V6 and V7. Replace defective component.
4. Power indicator lamp lights; voltmeter does not indicate on all ranges.	<ul style="list-style-type: none"> a. Power supply or voltage regulator circuits defective. b. Rectifier CR3 or circuit component defective. c. Diode CR1 or CR2 defective. 	<ul style="list-style-type: none"> a. Check tubes V6, V9, V7, and V8 in turn. Check high-voltage winding of transformer T1. Replace defective component. b. Check for 12.6 volts dc across output of rectifier CR3. Check resistors R66 and R68. If tubes V1 and V2 are not lighted, check capacitor C39. Replace defective component. c. Replace diode (paragraph 5-15).
5. Meter indication normal on low ranges (.001 to .3 volts). Meter sensitivity distorted on high-voltage ranges (1 to 300 volts).	Compensated 1000:1 divider defective.	Check C4 and R4. Replace defective component.
6. Meter indicates low on all ranges.	<ul style="list-style-type: none"> a. Low amplifier gain. b. Diode CR1 or CR2 defective. 	<ul style="list-style-type: none"> a. Check B+ voltage (paragraph 5-20). Check tubes V2 through V5 for low emission. If any tube is replaced, check and recalibrate the voltmeter (paragraph 5-22). b. Replace diode (paragraph 5-15).
7. Meter indication unstable or erratic.	<ul style="list-style-type: none"> a. Power supply, circuit defective. b. Amplifier tube V1, V2, V3, V4, and V5 defective. 	<ul style="list-style-type: none"> a. Check heaters and B+ voltage. Replace defective component. b. Check V1 through V5 for microphonics or noise. If tube is replaced, check and recalibrate the voltmeter (paragraph 5-22).
8. Meter indication normal on .001 and 1 volt range. Meter sensitivity distorted on all other ranges (.003, .01, .03, .1, .3, 3, 10, 30, 100, and 300 volts).	Faulty RANGE switch S1.	Check switch contacts of S1. Replace RANGE switch S1 if defective (paragraph 5-16).

Figure 5-5. Trouble-Shooting Procedure

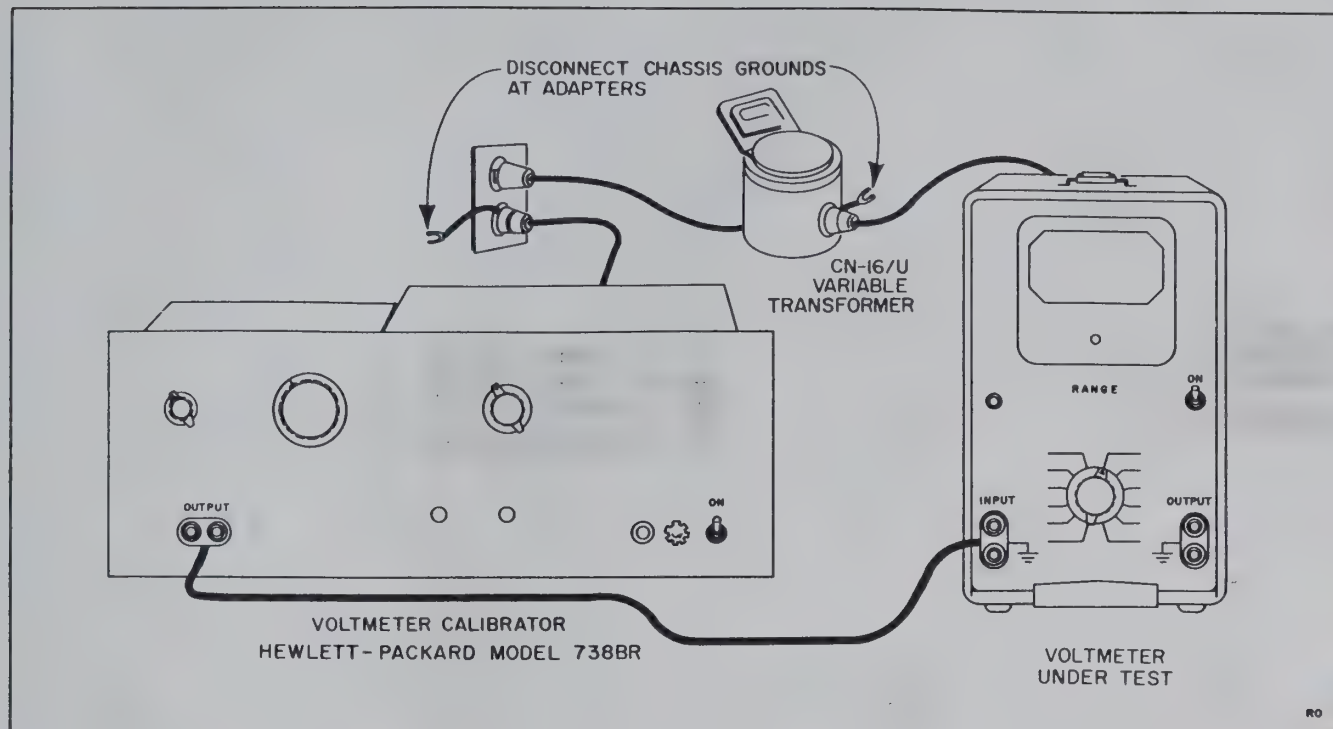


Figure 5-6. Test Setup for Calibration Check and Adjustments

The residual reading on voltmeter must be no higher than the residual reading obtained with voltmeter INPUT terminated with a 10-megohm resistor and shielded to prevent stray pickup. If the residual reading is higher when connected to the calibrator, refer to paragraph 3-12.

e. Set the voltmeter RANGE switch to .001. Set the voltmeter calibrator to provide .001 volt rms (400 cps) output. Record deviation of voltmeter reading from 1 on the voltmeter scale.

f. Set the voltmeter RANGE switch to 1. Set the voltmeter calibrator to provide 1 volt rms output. Record deviation of voltmeter reading from 1 on the voltmeter scale.

g. Still using the voltmeter 1-volt range, reduce the voltmeter calibrator output in 0.1 volt steps. Record deviation of voltmeter readings from each 0.1 volt calibration mark.

h. Compare recorded deviations with the permissible errors listed in the performance specifications in figure 1-2.

i. Connect the voltmeter as shown in figure 5-7 and set line voltage to 115. (This setup measures calibration accuracy at low and high frequencies.)

j. Set voltmeter RANGE switch to .001. Set frequency response test set OUTPUT ATTENUATOR to .001 to measure the lowest voltmeter range; initially set AMPLITUDE control for 0 volts output. Then note volt-

meter reading; it must not be higher than the residual reading noted in step d.

k. Turn the frequency response test set RANGE SELECTOR to EXTERNAL. Set the external oscillator frequency to 400 cps; adjust the oscillator output level to obtain a reading of .9 on the 0 to 1 VOLTS scale of the voltmeter. Then adjust the METER SET control on the frequency response test set to obtain a standard meter indication at the SET LEVEL mark on the test set meter.

l. Tune the external oscillator to 10 cps and adjust its output level to keep the frequency response test set meter reading at SET LEVEL. Do not adjust the METER SET control as this would alter the fixed monitoring point of the meter. Record the voltmeter deviation from .9 on the scale. This reading must be between 0.85 and 0.95 to be within specifications.

m. Set the RANGE SELECTOR on the test set to 3-10 mc, set the FREQ. TUNING dial to 4, and adjust the AMPLITUDE control to keep the frequency response test set meter reading at SET LEVEL. Record the voltmeter deviation from .9 on the scale. This reading must be between 0.85 and 0.95 to be within specifications. The gain and frequency response of the basic voltmeter amplifier is now tested.

n. Repeat step m using line voltages of 103 and 127. Record voltmeter deviation from .9 on the scale.

o. Set voltmeter RANGE switch to .003 and also set the frequency response test set OUTPUT ATTENUATOR to .003 to check this voltmeter range. Repeat steps k and m. Record voltmeter deviation from .9 on the scale.

hp 400D/H/L



HEWLETT-PACKARD COMPANY / OPERATING AND SERVICE MANUAL

400D/H/L

VACUUM TUBE


VOLTMETER

INCLUDING HO2-400D

hp 400D/H/L

CERTIFICATION

THE HEWLETT-PACKARD COMPANY CERTIFIES
THAT THIS INSTRUMENT WAS THOROUGHLY
TESTED AND INSPECTED AND FOUND TO
MEET ITS PUBLISHED SPECIFICATIONS WHEN
IT WAS SHIPPED FROM THE FACTORY.

 FURTHER CERTIFIES THAT ITS CALIBRATION
MEASUREMENTS ARE TRACEABLE TO THE
NATIONAL BUREAU OF STANDARDS TO THE
EXTENT ALLOWED BY THE BUREAU'S CALI-
BRATION FACILITY.



OPERATING AND SERVICE MANUAL

( PART NO. 400D/H/L-902)

MODEL 400D

SERIALS PREFIXED: 310-

MODEL 400H

SERIALS PREFIXED: 313-

MODEL 400L

SERIALS PREFIXED: 313-

AND

SPECIF. H02-400D

SERIALS PREFIXED: 310-

VACUUM TUBE VOLTMETER

Appendix B, Manual Backdating
Changes adapts this manual to:

Models 400D/H02-400D,	Serial Nos. 310-45570 and below
Models 400H/L,	Serial Nos. 313-22176 and below
Model 400H,	Serial Nos. 017-12026 and below
Model 400L,	Serial Nos. 048-13256 and below
Models 400DR/HR/LR,	All Serial Nos.

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TABLE OF CONTENTS

Section	Page	Section	Page
I GENERAL DESCRIPTION	1-1	5-22 Testing Voltmeter Performance . .	5-5
1-1 Introduction	1-1	5-24 Calibration and Frequency Response Adjustments	5-8
1-4 Description	1-1	VI ILLUSTRATED PARTS	
1-11 Accessories	1-2	BREAKDOWN	6-1
II INSTALLATION	2-1	6-1 General	6-1
2-1 Unpacking and Inspection	2-1	VII GROUP ASSEMBLY PARTS	
2-3 Line Voltage Requirement	2-1	BREAKDOWN	7-1
2-5 Power Line Connections	2-1	7-1 Vacuum Tube Voltmeter 400D/H/L	7-1
2-8 Installation	2-1	7-2 Main Chassis Assembly	7-3
2-10 Operation Check	2-1	7-3 Range Switch Assembly 400D-19A	7-8
III OPERATING INSTRUCTIONS	3-1	7-4 Printed Circuit Board Assembly 400D-75G	7-9
3-1 Instrument Turn-On	3-1	7-5 Printed Circuit Board Assembly 400D-75F	7-11
3-3 General Operating Information . . .	3-1	7-6 Printed Circuit Board Assembly 400D-65C	7-12
3-12 Low-Level Measurements and Ground Currents	3-2	VIII NUMERICAL INDEXES	8-1
3-14 Measurement of Voltage	3-2	Part No. Numerical Index	8-1
3-17 Measurement of Decibels	3-3	Hewlett-Packard Stock No. Index	8-2
3-20 Impedance Correction Graph	3-3	IX REFERENCE DESIGNATION INDEX	9-1
3-22 Use of Voltmeter Amplifier	3-4		
IV CIRCUIT DESCRIPTION	4-1		
4-1 Block Diagram	4-1		
4-3 Input Voltage Divider and Step Attenuator	4-1		
4-7 Broadband Voltmeter Amplifier . . .	4-1		
4-10 Indicating Meter Circuit	4-1		
4-14 Power Supply	4-2		
V MAINTENANCE	5-1		
5-1 Scope	5-1		
5-3 Precautions	5-1		
5-5 Test Equipment Required	5-1		
5-7 Meter Zero Adjustment	5-1		
5-9 Cabinet Removal	5-2		
5-10 Tube Replacement	5-2		
5-13 Replacement of Special Parts	5-2		
5-17 Trouble Shooting	5-3		
5-20 Testing the Power Supply	5-3		

Appendix

A CODE LIST OF MANUFACTURERS

Appendix

B SALES AND SERVICE OFFICES

Appendix

C MANUAL BACKDATING CHANGES

LIST OF ILLUSTRATIONS

Number	Title	Page	Number	Title	Page
1-1.	Vacuum Tube Voltmeters Models 400D, 400H, and 400L	1-0	5-6.	Test Setup for Calibration Check and Adjustments	5-7
1-2.	Table of Specifications	1-1	5-7.	Test Setup for Frequency Response Check and Adjustment	5-8
3-1.	Voltmeter Front Panel, Showing Controls and Connectors	3-0	5-8.	Voltage and Resistance Diagram	5-10
3-2.	Effect of Harmonics on Voltage Measurements	3-1	5-9.	Diagram of RANGE Switch	5-11
3-3.	Test Setup for Avoiding Ground Loop	3-2	5-10.	Voltmeter Schematic Diagram	5-13
3-4.	Impedance Correction Graph	3-5	7-1.	400D/H/L Vacuum Tube Voltmeter . .	7-1
4-1.	Voltmeter Block Diagram	4-0	7-2.	Main Chassis Assembly (Sheet 1 of 2)	7-3
4-2.	Simplified Schematic of Meter Bridge Circuit	4-2	7-2.	Main Chassis Assembly (Sheet 2 of 2)	7-5
5-1.	Test Equipment Required	5-1	7-3.	RANGE Switch Assembly	7-8
5-2.	Adjustments Required When Tubes Are Replaced	5-2	7-4.	Printed Circuit Board Assembly Part No. 400D-75G	7-9
5-3.	Left Side View of Voltmeter Chassis .	5-4	7-5.	Printed Circuit Board Assembly Part No. 400D-75F	7-10
5-4.	Right Side View of Voltmeter Chassis	5-5	7-6.	Printed Circuit Board Assembly Part No. 400D-65C	7-12
5-5.	Trouble-Shooting Procedure	5-6			

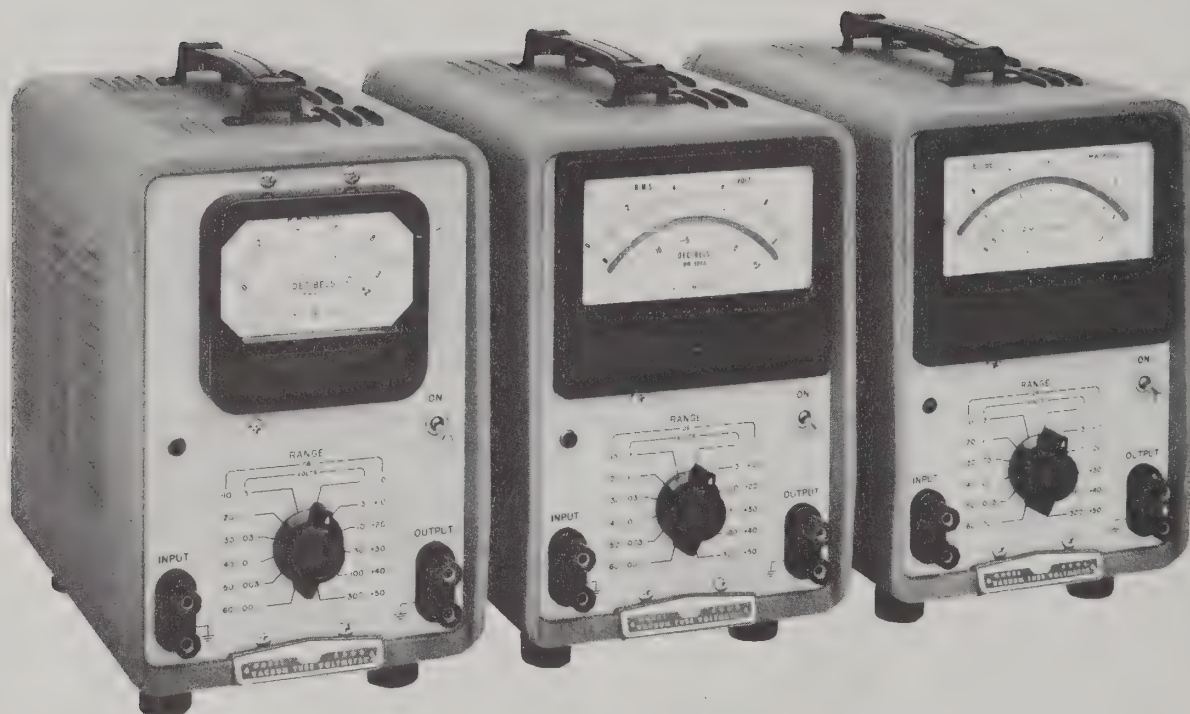


Figure 1-1. Vacuum Tube Voltmeters Models 400D, 400H, 400L

SECTION I

GENERAL DESCRIPTION

1-1. INTRODUCTION. (See figure 1-1.)

1-2. This manual contains operating and servicing instructions, and a parts breakdown, for the Models 400D, 400H, and 400L Vacuum Tube Voltmeters manufactured by the Hewlett-Packard Company. The Model 400D Voltmeter is similar to a military counterpart, Electronic Voltmeter ME-30A/U, in appearance and operation, but contains modified electrical circuits to obtain improved performance. Applicable Federal Stock Numbers for the voltmeters are as follows:

Model 400D: 6625-643-1670
 Model 400H: 6625-557-8261
 Model 400L: 6625-729-8360

1-3. The Models 400D, 400H, and 400L Voltmeters are the same except for the differences listed in Figure 1-2.

a. The front panel meters are different in each model, as described in paragraph 1-6.

b. The accuracy specifications are different for each model, as described in figure 1-2.

1-4. DESCRIPTION.

1-5. The Hewlett-Packard Models 400D, 400H, and 400L Vacuum Tube Voltmeters are general purpose, portable electronic a-c voltmeters of high sensitivity and stability. They are suited to both laboratory and field use. Models 400D/H measure a-c voltages from 0.001 to 300 volts and Model 400L from .003 to 300 volts rms full scale, with a frequency bandwidth covering 10 cps to 4 megacycles. The voltmeters are compact, accurate, and rugged and have fast meter response, high input impedance, stable calibration accuracy, and freedom from the effects of normal line voltage variations. The voltmeters are designed for long instrument life with a minimum of servicing.

a. Voltage Range: 400D/H - 0.1 millivolt to 300 volts; 400L - 0.3 millivolt to 300 volts, in 12 ranges providing full-scale readings of the following voltages:

0.001	0.100	10.00
0.003	0.300	30.00
0.010	1.000	100.00
0.030	3.000	300.00

b. Decibel Range: -72 to +52 db, in 12 ranges.

c. Frequency Range: 10 cps to 4 mc.

d. Input Impedance: 10 megohms shunted by 15 pf (15 $\mu\mu\text{f}$) on ranges 1.0 volt to 300 volts; 25 pf on ranges 0.001 volt to 0.3 volt.

e. Stability: Line voltage variations of $\pm 10\%$ do not reduce the specified accuracy, and line voltage transients are not reflected in the meter reading. Electron tube deterioration to 75% of normal transconductance affects accuracy less than 0.5% from 20 cps to 1 mc.

f. Amplifier: OUTPUT terminals are provided so that the voltmeter can be used to amplify small signals or to enable monitoring of waveforms under test with an oscilloscope. Output voltage is approximately 0.15 volt rms on all ranges with full-scale meter deflection. Amplifier frequency response is same as the voltmeter. Internal impedance is approximately 50 ohms over entire frequency range.

g. Accuracy: Model 400D -

$\pm 2\%$ of full scale, 20 cps to 1 mc;
 $\pm 3\%$ of full scale, 20 cps to 2 mc;
 $\pm 5\%$ of full scale, 10 cps to 4 mc.

Model 400H -

$\pm 1\%$ of full scale, 50 cps to 500 kc;
 $\pm 2\%$ of full scale, 20 cps to 1 mc;
 $\pm 3\%$ of full scale, 20 cps to 2 mc;
 $\pm 5\%$ of full scale, 10 cps to 4 mc.

Model 400L -

$\pm 2\%$ of reading or $\pm 1\%$ of full scale, whichever is more accurate, 50 cps to 500 kc.
 $\pm 3\%$ of reading or $\pm 2\%$ of full scale, whichever is more accurate, 20 cps to 1 mc.
 $\pm 4\%$ of reading or $\pm 3\%$ of full scale, whichever is more accurate, 20 cps to 2 mc.
 $\pm 5\%$ of reading 10 cps to 4 mc.

h. Power Requirement: 115/230 volts $\pm 10\%$, 50 to 1000 cps, approximately 100 watts.

i. Size: 11-3/4 in. high, 7-1/2 in. wide, 12 in. deep.

j. Weight: 18 lbs; shipping weight approximately 23 lbs.

Figure 1-2. Table of Specifications

1-6. Each model voltmeter has three calibrated scales on the panel meter. The Models 400D and 400H have two linear VOLTS scales, 0 to 1 and 0 to 3, and one DECIBELS scale, -12 to +2 db. The meters used in the Models 400H and 400L are larger and include a mirror to eliminate parallax in viewing and to facilitate use of the higher scale calibration accuracy of these models. The Model 400L VOLTS scales are logarithmic in calibration, from 0.3 to 1 and 0.8 to 3; and the DECIBELS scale is linear. In all models, the VOLTS scales are calibrated to indicate the root-mean-square (rms) value of an applied sine wave. Actual meter deflection is proportional to the average value of the applied signal, thereby minimizing additional meter deflection due to noise and harmonic distortion.

1-7. A voltmeter output signal is provided at the front panel OUTPUT terminals. This output is proportional to the meter reading and has a waveshape similar to the applied signal. This signal level is about 0.15 volts rms for a full-scale meter reading, regardless of the input signal level. The internal impedance at the OUTPUT terminal is 50 ohms over the full frequency range. High-impedance loads (above 100K) will not adversely affect the accuracy of the voltmeter. This output is valuable for increasing the sensitivity of bridges, etc., where distortion added to the waveform is not a factor.

1-8. The voltmeter chassis is constructed of aluminum alloy throughout. The panel is finished in non-reflecting, light-grey baked enamel; the cabinet is finished in dark-blue, baked wrinkle paint. The cabinet is equipped with rubber feet and a leather carrying handle. Control markings on the front panel are engraved and black filled. INPUT and OUTPUT terminals are special binding posts which accept either bare wire or banana plugs; the 3/4-inch spacing between binding posts accepts standard dual-banana plugs. The "ground" side of the INPUT and OUTPUT terminals is connected to the instrument chassis which is in turn connected to the power line ground through the third (round) prong of the plug on the power cable.

1-9. The voltmeter is equipped with a non-detachable power cord. Test leads, which may be plain wire leads or coaxial cable, and test probes must be supplied by the user.

1-10. Instruments designated Models 400DR, 400HR, and 400LR are rack mount configurations of the 400D, 400H, and 400L, respectively. They are identical to their cabinet model counterparts in every other respect. They are designed to be mounted in a standard 19 inchwide x 7 inch high relay rack space. Refer to Appendix C for Replacement Parts information.

1-11. ACCESSORIES.

1-12. Accessory instruments for the voltmeter are available (not supplied) to increase its range of operation and application, such as increasing voltage measurement range and input impedance, converting to current measurement, providing line matching, etc., as follows:

a. H-P 11004A Line Matching Transformer. Provides balanced 135-ohm or 600-ohm input, 5 kc to 600 kc.

b. H-P 11005A Bridging Transformer. Allows voltage measurement on balanced lines. 20 cps to 45 kc.

c. H-P 11039A Capacitive Voltage Divider. Safely measures power-frequency voltages to 25 kilovolts. Division ratio, 1000:1. Input capacity, 15 pf \pm 1 pf.

d. H-P 11041A Capacitive Voltage Divider. Accuracy \pm 3%. Division ratio, 100:1. Input impedance, 50 megohms, resistive, shunted with 2.75 pf capacity. Maximum voltage, 1500 volts.

e. H-P 456A AC Current Probe. Allows current measurements without breaking the circuit. Sensitivity 1 mv/ma \pm 2% at 1 kc. Maximum input 1 amp rms; 2 amp peak. Output noise less than 50 μ v rms.

f. H-P 11029A-11034A Shunt Resistors. For measuring currents as small as 1 microamp full scale. Accuracy \pm 1% to 100 kc, \pm 5% to 4 mc (470A, \pm 5% to 1 mc). Maximum power dissipation, 1 watt.

SECTION II

INSTALLATION

2-1. UNPACKING AND INSPECTION.

2-2. There are no special precautions for unpacking the voltmeter. Save the shipping carton and packing materials for possible storage or reshipment. When unpacking, inspect instrument and packing materials for signs of damage in shipment. Make an operation check as directed in paragraph 2-10 to determine if performance is satisfactory. If there is any indication of damage, immediately file a claim with the transport service used or other cognizant authority.

2-3. LINE VOLTAGE REQUIREMENT.

2-4. The voltmeter is wired at the factory for use on 115-volt a-c power. This voltage may vary $\pm 10\%$ without adverse effect upon voltmeter performance. The voltmeter can be wired for use on 230-volt a-c power by reconnecting the dual primary windings on the power transformer as shown in the schematic diagram in Section V. When using 230-volt power, change from a 1-amp to a 1/2-amp slow-blow fuse. If necessary, provide an adapter for attaching the standard 115-volt plug on the voltmeter to the 230-volt outlet.

2-5. POWER LINE CONNECTION.

2-6. The three-conductor power cable on the voltmeter is terminated in a polarized three-prong male connector. The third contact is an offset round pin added to a standard two-blade connector, which grounds the instrument chassis when used with the appropriate receptacle. To connect this plug in a standard two-contact receptacle, use an adapter. The chassis ground connection is brought out of the adapter in a green pigtail lead for connection to a suitable ground.

2-7. The power plug normally supplied with the voltmeter is made of molded rubber and is an integral part of the power cable. On certain military contracts, a modification of the Model 400D, termed the H02-400D, is equipped with a removable plug having the same pin configuration but constructed of corrosion-resistant material. In all other respects the H02-400D is the same as the Model 400D and carries the same Federal Stock Number.

WARNING

The lower INPUT and OUTPUT signal terminals on the panel of the voltmeter are connected directly to the chassis of the voltmeter. Any voltage applied to the lower terminal will be shorted directly to ground. If the ground connection in the power cord is disconnected by use of an adapter, the entire voltmeter cabinet will carry whatever potential is applied to the lower terminal and may be a hazard to the operator.

2-8. INSTALLATION.

2-9. The voltmeter is a portable instrument requiring no permanent installation. The voltmeter is for bench-top operation, standing on its rubber feet with its front panel near the vertical plane. A bail is provided for raising the front of the cabinet to obtain a better viewing angle.

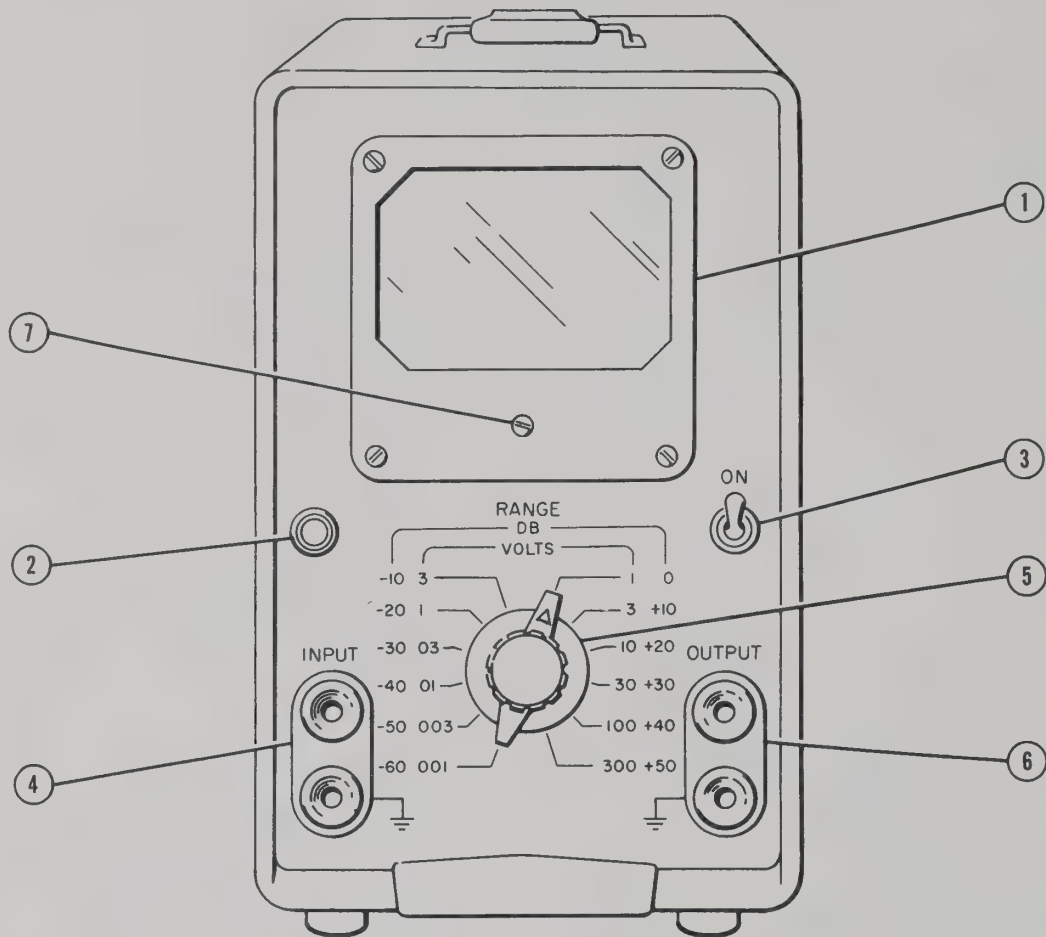
2-10. OPERATION CHECK.

2-11. The voltmeter is ready for use as received from the factory. The simple check described below can be made by incoming inspectors to determine if electrical damage was incurred in shipment. If more complete proof of instrument performance is required, the over-all performance check described in paragraph 5-22 must be used. Make a simple performance check as follows:

a. Connect voltmeter to the power line through a variable transformer. Set transformer for 115 volts, turn on and allow a five-minute warmup.

b. Measure any sine wave voltage, excepting the power line, from 0.01 to 300 volts whose exact voltage is known. Note that the lower INPUT terminal is connected to the power line ground.

c. While making the above measurement, adjust the line voltage from 103 to 127 volts. The reading on the meter must not change by more than the width of the pointer.



RO

REFERENCE NUMBER	DESIGNATION	FUNCTION
1	Panel meter	Indicates rms volts and decibels of sine wave signals.
2	Indicator light	Indicates that voltmeter is turned on.
3	ON Power switch	Applies line power to voltmeter.
4	INPUT terminals	Receive voltage to be measured or signal to be amplified.
5	RANGE (DB-VOLTS) switch	Selects full-scale deflection sensitivity.
6	OUTPUT terminals	Supply signal level proportional to meter reading, with same waveform as applied to INPUT terminals.
7	Zero adjust screw	Meter zero adjust screw (for 400D and 400H only).

Figure 3-1. Voltmeter Front Panel, Showing Controls and Connectors

SECTION III

OPERATING INSTRUCTIONS

3-1. INSTRUMENT TURN-ON.

3-2. The voltmeter is ready for use as received from the factory and will give specified performance after a few minutes warmup. See Section II for information regarding connection to the power source and to the voltage to be measured. Controls are shown in figure 3-1.

3-3. GENERAL OPERATING INFORMATION.

3-4. **METER ZERO CHARACTERISTIC.** When the Model 400D and 400H Voltmeters are turned off, the meter pointer should rest exactly on the zero calibration mark on the meter scale. If it does not, zero-set the meter as instructed in paragraph 5-7. The meter supplied in the Model 400L Voltmeter is not provided with a mechanical meter zero adjustment. When the voltmeter is turned on with the INPUT terminals shorted, the meter pointer may deflect upscale slightly; this deflection does not affect the accuracy of a reading.

NOTE

When the voltmeter RANGE switch is set to the lowest ranges and the INPUT terminals are not terminated or shielded, noise pickup can be enough to produce up to full-scale meter deflection. This condition is normal and is caused by stray voltages in the vicinity of the instrument. For maximum accuracy on the .001-volt range, the voltage under measurement should be applied to the voltmeter through a shielded test lead.

3-5. **METER SCALES.** The two voltage scales on each of the voltmeter models are related to each other by a factor of $1:\sqrt{10}$ (10 db). In conjunction with the calibrated RANGE switch steps, this provides an intermediate range step spaced 10 db between "power of ten" ranges, which are 20 db apart. The relationship of the DECIBELS scale to the 0 to 1 VOLT scale is determined by making 0 db on the DECIBELS scale equal to the voltage required to produce 1 milliwatt in 600 ohms (0.775 volts). Thus, the DECIBELS scale reads directly in dbm (decibels referred to one milliwatt) across a 600-ohm circuit, and can be used to measure absolute level of sine wave signals. It can also be used to measure relative levels of any group of signals which have the same waveform, across any constant circuit impedance. The RANGE switch changes voltmeter sensitivity in 10-db steps accurate to within $\pm 1/8$ db. The RANGE switch position indicates the value of a full-scale meter reading.

3-6. **CONNECTIONS.** Voltmeter test leads must be provided by the user. The type of leads and probes used will depend upon the application, as listed below:

a. For connection to low-impedance signal sources, plain wire leads often are sufficient.

b. For high-impedance sources, or where noise pickup is a problem, low-capacity shielded wire must be used with a shielded, dual banana plug for connection to the voltmeter terminals.

c. If a probe is used, it should also be shielded to prevent pickup from the hand.

d. For signals above a few hundred kilocycles, the capacity of the test leads must be kept to a minimum by using very short leads, preferably unshielded. An alligator clip should be used at the test end so that connection can be made without adding the capacity of the user's hands.

3-7. **MAXIMUM INPUT VOLTAGE.** Do not apply more than 600 volts dc to the INPUT terminals. To do so exceeds the voltage rating of the input capacitor.

3-8. If an applied voltage momentarily exceeds the selected full-scale voltmeter sensitivity, a few seconds may be required for circuit recovery, but no damage will result.

3-9. **INPUT VOLTAGE WAVEFORM.** The voltmeter is calibrated to indicate the root-mean-square value of a sine wave; however, meter pointer deflection is proportional to the average value of whatever waveform is applied to the input. If the input signal waveform is not a sine wave, the reading will be in error by an amount dependent upon the amount and phase of the harmonics present, as shown in figure 3-2 below. When harmonic distortion is less than about 10%, the error which results is negligible.

INPUT VOLTAGE CHARACTERISTICS	TRUE RMS VALUE	METER INDICATION
Fundamental = 100	100	100
Fundamental +10% 2nd harmonic	100.5	100
Fundamental +20% 2nd harmonic	102	100-102
Fundamental +50% 2nd harmonic	112	100-110
Fundamental +10% 3rd harmonic	100.5	96-104
Fundamental +20% 3rd harmonic	102	94-108
Fundamental +50% 3rd harmonic	112	90-116

Note: This chart is universal in application since these errors are inherent in all average-responding type voltage-measuring instruments.

Figure 3-2. Effect of Harmonics on Voltage Measurements

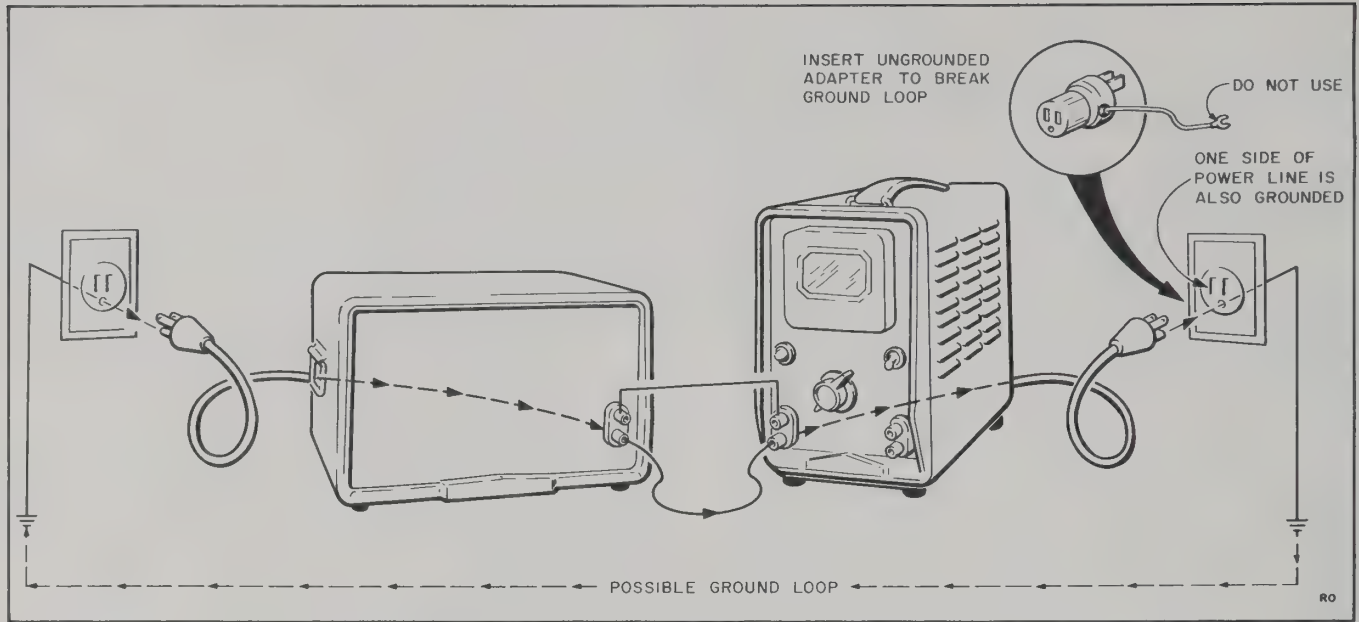


Figure 3-3. Test Setup for Avoiding Ground Loop

3-10. Since the voltmeter meter deflection is proportional to the average value of the input waveform, it is not adversely affected by moderate levels of random noise. The effect that noise has on the accuracy of the meter reading depends upon the waveform of the noise and upon the signal-to-noise ratio. A square wave has the greatest effect, a sine wave intermediate effect, and "white" noise has the least effect on the meter reading.

3-11. If the noise signal is a 50% duty cycle square wave and the signal-to-noise ratio is 10:1 (between peak voltages), the error will be about 1% of the meter reading. If the noise signal is "white" noise and the signal-to-noise ratio 10:1, the error is negligible.

3-12. LOW-LEVEL MEASUREMENTS AND GROUND CURRENTS.

3-13. When the voltmeter is used to measure signal levels below a few millivolts, ground currents in the meter test leads can cause an error in meter reading. Such currents are created when two or more ground connections are made between the instruments of a test setup and/or between the instruments and the power line ground. Two ground connections complete an electrical circuit (ground loop) for the voltages which are generated across all instrument chassis by stray fields, particularly the fields of transformers. These ground currents can be minimized by disconnecting the ground lead in the power cord from either the voltmeter or the signal source being measured, at the power outlet as shown in figure 3-3, and by making sure that in the test setup no other ground loop is formed that can cause a ground current to flow in the voltmeter test leads. Although the resultant voltage developed across a test lead is in the order of microvolts, it is enough to cause noticeable errors in measurements of a few millivolts. The presence of ground currents can sometimes be determined by simply changing the grounds for the instruments in the

setup and watching for a change in meter reading. If changing the ground system causes a change in meter reading, ground currents are present.

3-14. MEASUREMENT OF VOLTAGE.

3-15. The meter has two VOLTS scales, 0 to 1 and 0 to 3. When the RANGE switch is set to .001, .01, .1, 1, 10, or 100 VOLTS, read the 0 to 1 scale. When the RANGE switch is set to .003, .03, .3, 3, 30, or 300 VOLTS, read the 0 to 3 scale.

CAUTION

The lower (black) signal INPUT and OUTPUT terminals and the instrument case are connected to the power system ground when the instrument is used with a standard three-terminal (grounding) receptacle. Connect only ground-potential circuits to the black INPUT and OUTPUT terminals.

3-16. Operate the instrument as follows:

- Connect the voltmeter to the a-c power source.
- Turn the Power switch ON and allow a warmup period of approximately five minutes.
- Disconnect any external equipment from the OUTPUT terminals.
- Set the RANGE switch to the VOLTS range which will read the voltage to be measured at mid-scale or above. If in doubt, select a higher VOLTS range.
- Connect the voltage to be measured to the INPUT terminals.

CAUTION

AVOID A SHORT CIRCUIT ACROSS THE POWER LINE! To measure power line voltage, first connect only the upper (red) INPUT terminal to each side of the power line, in turn, leaving it connected to the side that causes meter indication. Then connect the lower (black) INPUT terminal (grounded internally) to the other side of the line. If this procedure is not followed, the power line may be short-circuited through the grounded INPUT terminal of the voltmeter.

f. Read the meter indication on the appropriate VOLTS scale, in accordance with the full-scale value indicated on the RANGE switch. Evaluate the reading in terms of the full-scale value indicated on the RANGE switch. Study the following examples:

Example 1

When the RANGE switch is in the .1 VOLTS range, read the 0 to 1 VOLTS scale. If the meter indicates .64 on that scale, the voltage being measured is:

$$.64 \text{ (meter indication)} \times \frac{.1 \left[\begin{array}{c} \text{switch-selected} \\ \text{voltage range} \end{array} \right]}{1 \text{ (full-scale value)}} = .064 \text{ volt}$$

Example 2

When the RANGE switch is in the 30 VOLTS range, read the 0 to 3 VOLTS scale. If the meter indicates 1.6 on that scale, the voltage being measured is:

$$1.6 \text{ (meter indication)} \times \frac{30 \left[\begin{array}{c} \text{switch-selected} \\ \text{voltage range} \end{array} \right]}{3 \text{ (full-scale value)}} = 16 \text{ volts}$$

3-17. MEASUREMENT OF DECIBELS.

3-18. The DECIBELS meter scale is provided for measuring dbm directly across 600 ohms and for measuring db ratio for comparison purposes when each measurement is made across the same circuit impedance. To measure signal level directly in dbm (0 dbm equals 1 milliwatt into 600 ohms) proceed as follows:

- Connect the voltmeter to the a-c power source.
- Turn the Power switch ON and allow a warmup period of approximately five minutes.
- Disconnect any external equipment from the OUTPUT terminals.
- Set the RANGE switch to the DB range which will give an upscale reading of the signal to be measured. If in doubt, select a higher-level scale.
- Connect the voltage to be measured to the INPUT terminals.

f. Note the meter indication on the DECIBELS scale (-12 to +2 db). The signal level is the algebraic sum of the meter indication and the db value indicated by the RANGE selector. Study the following examples:

Example 1

If the indication on the DECIBELS scale is +2 and the RANGE switch is in the +20 DB position, the level is +22 dbm.

Example 2

If the indication on the DECIBELS scale is +1.5 and the RANGE switch is in the -40 DB position, the level is -38.5 dbm.

3-19. To measure db across impedances other than 600 ohms, follow the above procedure and evaluate the results as follows:

NOTE

Since the measurement is made across other than 600 ohms, the level obtained in step f is in db, but not in dbm.

a. To obtain the difference in db between measurements made across equal impedances, algebraically subtract the levels being compared.

b. To obtain the reading of a single measurement in dbm, note the impedance across which the measurement is made and refer to the Impedance Correction Graph, described in paragraph 3-20.

c. To obtain the difference in dbm between measurements made across different impedances, convert each measurement to dbm using the Impedance Correction Graph described in paragraph 3-20. Then algebraically subtract the dbm levels being compared.

3-20. IMPEDANCE CORRECTION GRAPH.

3-21. As the voltmeter DECIBELS scale is calibrated to indicate dbm for measurements made across 600-ohm circuits, a correction factor must be used when measurements are made across circuit impedances other than 600 ohms, if absolute dbm levels are desired. The correction factor is not necessary in measuring relative db levels (not dbm) across the same impedance, but it is required for comparison of db levels measured across different impedances. The Impedance Correction Graph in figure 3-4 gives the correction factor for conversion of the meter reading to dbm when the impedance of the circuit under test is known. To use the graph, read the conversion factor corresponding to the test circuit impedance and add it to the meter reading determined by the method of paragraph 3-17. Observe the algebraic sign of the correction factor in making the algebraic addition. Use the following examples:

Example 1

If the measurement is made across 90 ohms, the indication on the DECIBELS scale is +2, and the RANGE switch is at the +30 DB position, the level in dbm is obtained as follows:

+ 2 (meter indication)
+30 (RANGE switch position)
+32 (sum)
+ 8 (correction factor from the Impedance
+40 dbm Correction Graph)

Example 2

For the same conditions as given above, except that the measurement is made across an impedance of 60,000 ohms, the level in dbm is obtained as follows:

+ 2 (meter indication)
+30 (RANGE switch position)
+32 (sum)
-20 (Correction factor from the Impedance
+12 dbm Correction Graph)

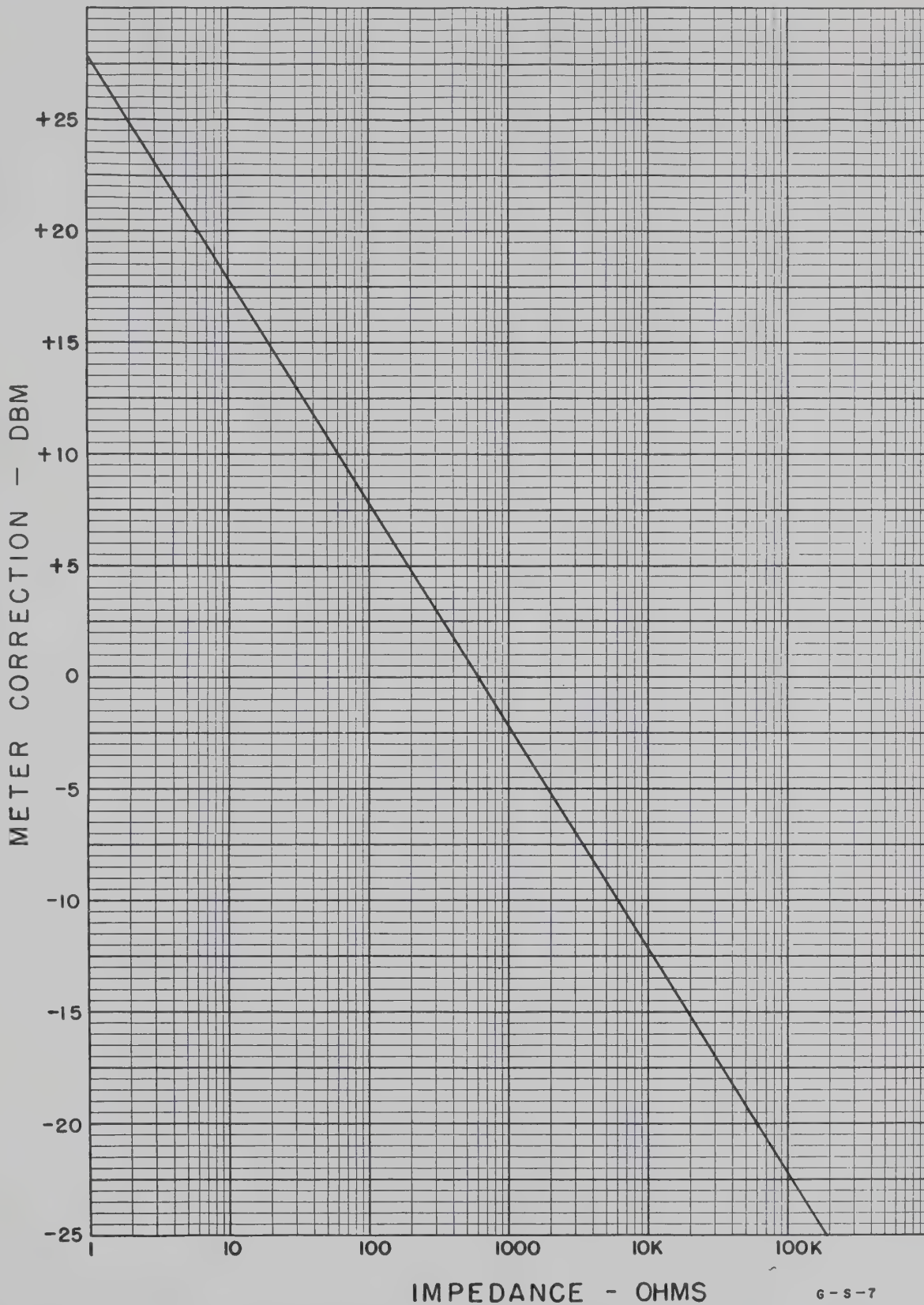
3-22. USE OF VOLTMETER AMPLIFIER.

3-23. The amplifier in the voltmeter may be used for amplifying weak signals. With full-scale meter deflection, the open-circuit output of the amplifier is approximately 0.15 volt rms regardless of the RANGE switch position. The impedance looking into the OUTPUT terminals is approximately 50 ohms. The frequency

response and calibration of the voltmeter may be affected by the impedance of a load applied to the OUTPUT terminals. To check the effect of the applied load: observe the meter reading obtained with no load connected to the OUTPUT terminals and then note any shift of reading when the external circuit is connected to the OUTPUT terminals. If the shift is negligible, the measurement is not being affected appreciably by the load. Whenever the input signal is changed, i.e., a different frequency or band of frequencies is applied, repeat the quick check described above.

3-24. Maximum gain from the amplifier is obtainable only on the lowest (.001 volts) range, since output level is the same for all bands. This is due to the 10-db amplification loss per step inserted by the RANGE switch as it is turned clockwise. Amplification may also be obtained on the .003, .01, .03, and 1 volt ranges.

3-25. When the voltmeter is used as an amplifier, select a range which gives a meter deflection near full scale. Off-scale signals more than twice the value of the position of the RANGE switch will cause severe distortion.



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Figure 3-4. Impedance Correction Graph

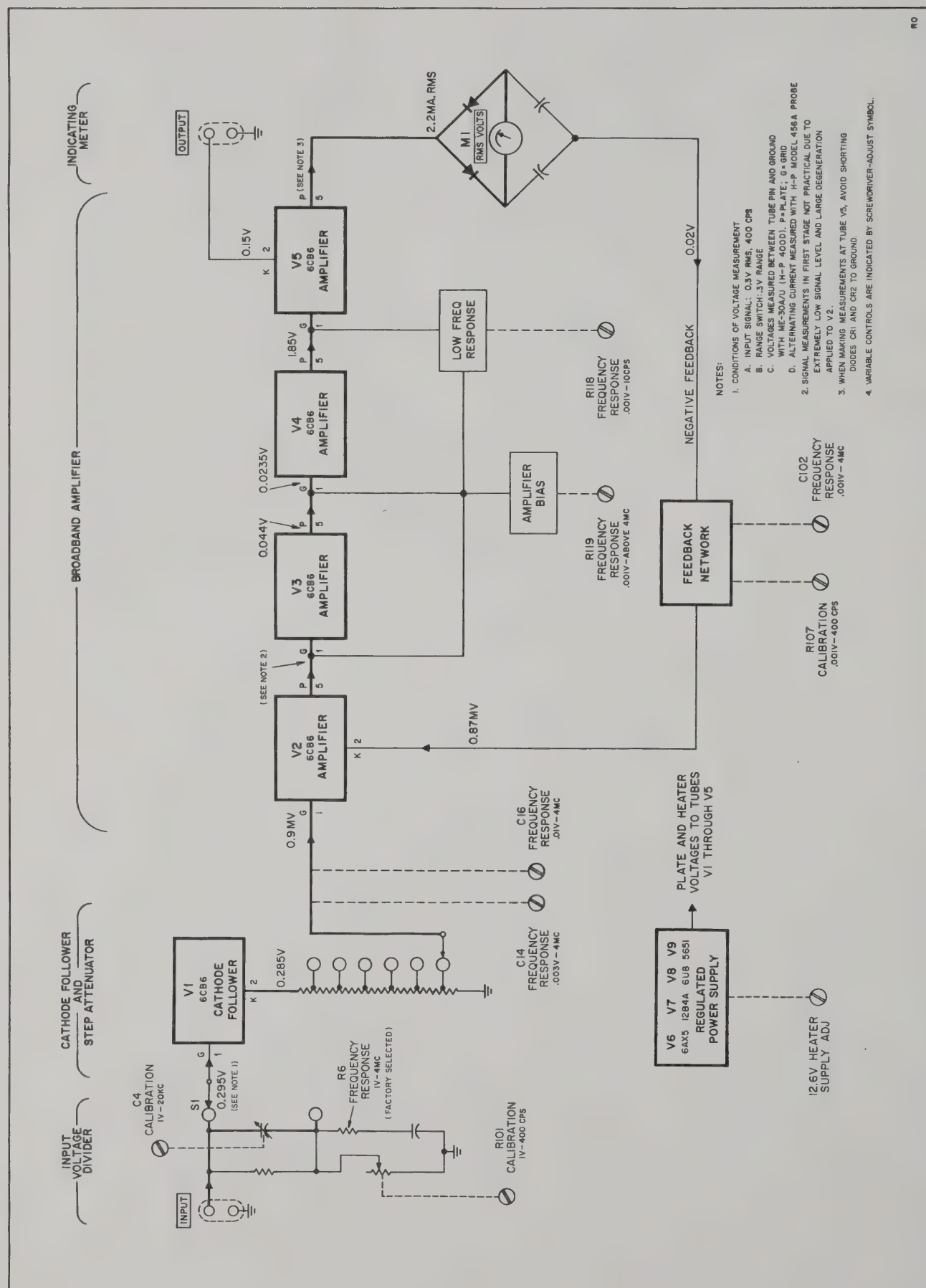


Figure 4-1. Voltmeter Block Diagram

SECTION IV

CIRCUIT DESCRIPTION

4-1. BLOCK DIAGRAM.

4-2. The electrical circuits of the voltmeter are shown in the block diagram in figure 4-1; they consist of an input voltage divider controlled by the RANGE switch, a cathode follower input tube, a precision step attenuator controlled by the RANGE switch, a broadband amplifier, an indicating meter, and a regulated power supply. The voltage applied to the INPUT terminals for measurement is divided by 1000 before application to the input cathode follower when the RANGE switch is set to the 1-volt range and higher; the input voltage is applied directly to the cathode follower on the lower ranges. The voltage from the cathode follower is divided in the precision attenuator to be less than 1 millivolt for application to the voltmeter amplifier. The output of the amplifier is rectified in a full-wave bridge rectifier with a d-c milliammeter across its midpoints. The resultant direct current through the meter is directly proportional to the input voltage.

4-3. INPUT VOLTAGE DIVIDER AND STEP ATTENUATOR.

4-4. The input voltage divider limits the signal level applied to the input cathode follower to less than 0.3 volt rms when voltages above this level are measured with the RANGE switch set at the 1-volt range or above. The divider consists of a resistive branch with one element made adjustable to obtain exact 1000:1 division at middle frequencies and a parallel capacitive branch with one element made adjustable to maintain exact 1000:1 division to beyond 4 megacycles. The input impedance of the voltmeter is established by this divider and is the same for all positions of the RANGE switch. On the six low-voltage positions of the RANGE switch, the input divider provides no attenuation of the input voltage. (See figure 5-10 for the complete schematic.)

4-5. The step attenuator in the cathode circuit of the input cathode follower reduces the voltage to be measured to 1 millivolt or less for application to the voltmeter amplifier. Each step of the attenuator lowers the signal level by exactly 10 db ($1:\sqrt{10}$). The attenuator consists of six precision wirewound resistors which are selected to very high accuracy and carefully mounted on a 12-position rotary switch. The RANGE switch rotor has two contactors (see figures 5-9 and 5-10); the first contacts each resistor in turn while the input divider is in the non-attenuating position; the second rotor finger repeats these contacts while the input attenuator is in the attenuating position. On the .001-volt range a fixed capacitor (C15) is automatically connected to provide flat frequency response beyond 4 megacycles. In the .003- and the .01-volt ranges, separate adjustable capacitors (C14, C16) are automatically connected to the attenuator to permit setting the frequency response at 4 megacycles. C14 and C16 are also connected to the attenuator on the 3- and 10-volt ranges. Fixed capacitor C106 (permanently connected) flattens frequency response on the .03- and 30-volt ranges.

4-6. Cathode follower V1 provides a constant, high input impedance to the input voltage divider and INPUT terminals of the voltmeter and provides a relatively low impedance in its cathode circuit to drive the step attenuator. The voltage gain factor across V1 is 0.95.

4-7. BROADBAND VOLTMEETER AMPLIFIER.

4-8. Amplification of the signal voltage is provided by a four-stage stabilized amplifier consisting of tubes V2 through V5 and associated circuits. The amplifier provides between 55- and 60-db gain with about 55 db of negative feedback at mid-frequencies. The feedback signal is taken from the plate of the output amplifier (V5) through the meter rectifiers and gain-adjusting circuit to the cathode of the input amplifier (V2). Variable resistor R107 in the feedback network adjusts the negative feedback level to set the basic gain of the amplifier at mid-frequencies, while adjustable capacitor C102 permits setting amplifier gain at 4 megacycles. Variable resistor R118 in the coupling circuit between V4 and V5 permits adjusting the gain of the amplifier at 10 cycles per second by controlling the phase shift of low-frequency signals between these two stages (increasing phase shift decreases degeneration and increases gain).

4-9. Variable resistor R119 in the grid return path for V3, V4, and V5 adjusts the total transconductance of these tubes in order to restrict the maximum gain-bandwidth product of the amplifier. The gain-bandwidth product must be restricted to give a smooth frequency response rolloff above 4 megacycles and to prevent possible unstable operation at frequencies far above 4 megacycles when tubes having unusually high transconductance are used (tube transconductance tolerances during manufacture permit wide variations in new tubes; the adjustment permits the use of such tubes). The plate voltage from V5 is rectified by the meter rectifiers and drives the feedback network. The cathode voltage of V5 is fed to the meter OUTPUT terminals for monitoring purposes. The current through V5, and thus the signal voltage at the cathode, is affected by the loading of the meter rectifiers. For signal levels causing third-scale or more meter deflection, this distortion consists of a very small irregularity near 0 volts on the waveform as each diode begins conduction.

4-10. INDICATING METER CIRCUIT.

4-11. The meter rectifier circuit consists of two silicon diodes and two capacitors connected as a bridge with the indicating meter across the mid-points as shown in figure 4-2. The diodes provide full-wave rectification of the signal current for operating the meter. Electron flow through the meter is supplied in the following manner (see figure 4-2). During the positive-going half cycle of plate voltage on V5, rectifier CR1 conducts electrons from both C32 and C33 back to the B+ buss. The portion of electrons from C33 flows through the meter on the way to B+. At this point in the cycle, both C32 and C33 are charged to the potential of B+ less some small drop in R51 and R52.

4-12. During the negative-going half cycle of the plate voltage of V5, rectifier CR2 conducts electrons back to both C32 and C33 from the plate of V5. That portion of electrons going back to C32 flows through the meter on the way (in the same direction that the electrons flowed in the first, positive, half cycle). At this point in the cycle, both C32 and C33 are discharged. The pulsating current through the meter is smoothed by C34 to prevent meter pointer vibration when measuring low-frequency signals. The current is proportional to the arithmetic average value of the waveform amplitude of the signal. Meter calibration in rms volts is based on the mathematical ratio between the average and rms values of true sine wave current.

4-13. In addition, the bridge serves as a segment of a voltage divider (in series with L11 and R108) connected across the output of the amplifier. The negative feedback voltage fed to the input of the amplifier is obtained across L11 and R108. The alternating charge and discharge of C32 and C33 produce at their junction with L11 an alternating current of the same phase and waveform as that at the plate of V5. This phase is negative with respect to the input signal applied to the first stage of the amplifier (V2), and drives the negative feedback network.

4-14. POWER SUPPLY.

4-15. The power supply consists of tubes V6 through V9 and the associated circuits, as shown in the complete

schematic diagram, figure 5-10. The power supply furnishes regulated +250V d-c voltage for the grid and plate bias circuits of tubes V1 through V5, unregulated 12.6V d-c voltage for the heater supply of tubes V1 through V4, and 6.3V a-c voltage for the heater supply of tubes V5 through V8. The power supply is designed to operate from either a 115-volt ($\pm 10\%$) or a 230-volt ($\pm 10\%$) a-c power source of 50 to 1000 cps. The primary winding of power transformer T1 is arranged in two sections, which can be strapped either in parallel or in series, to permit operation on 115V or 230V, respectively.

4-16. The output of rectifier V6 is applied to the voltage regulator circuit consisting of V7 through V9 which supplies a constant, +250 volts dc to the stabilized amplifier circuit of the voltmeter. Tube V7 is the series regulator tube, and V9 provides a fixed reference voltage drop, with which the output voltage is compared in amplifier V8B. V8A is a cathode follower which couples the reference voltage from V9 to V8B without loading V9. The regulated output voltage is applied to the control grid of V8B, while the reference voltage is applied to its cathode. The difference between the control grid and cathode voltages controls the operating point of V8B and thus its plate voltage, which in turn supplies the grid voltage for regulator V7. Any change in the regulated output of V7 produces a correcting change in the grid bias of V7 through the action of V8B, thus maintaining an essentially constant output voltage despite changes in line voltage or load on the supply. The gain of V8B is high enough to keep the output at the V7 cathode regulated

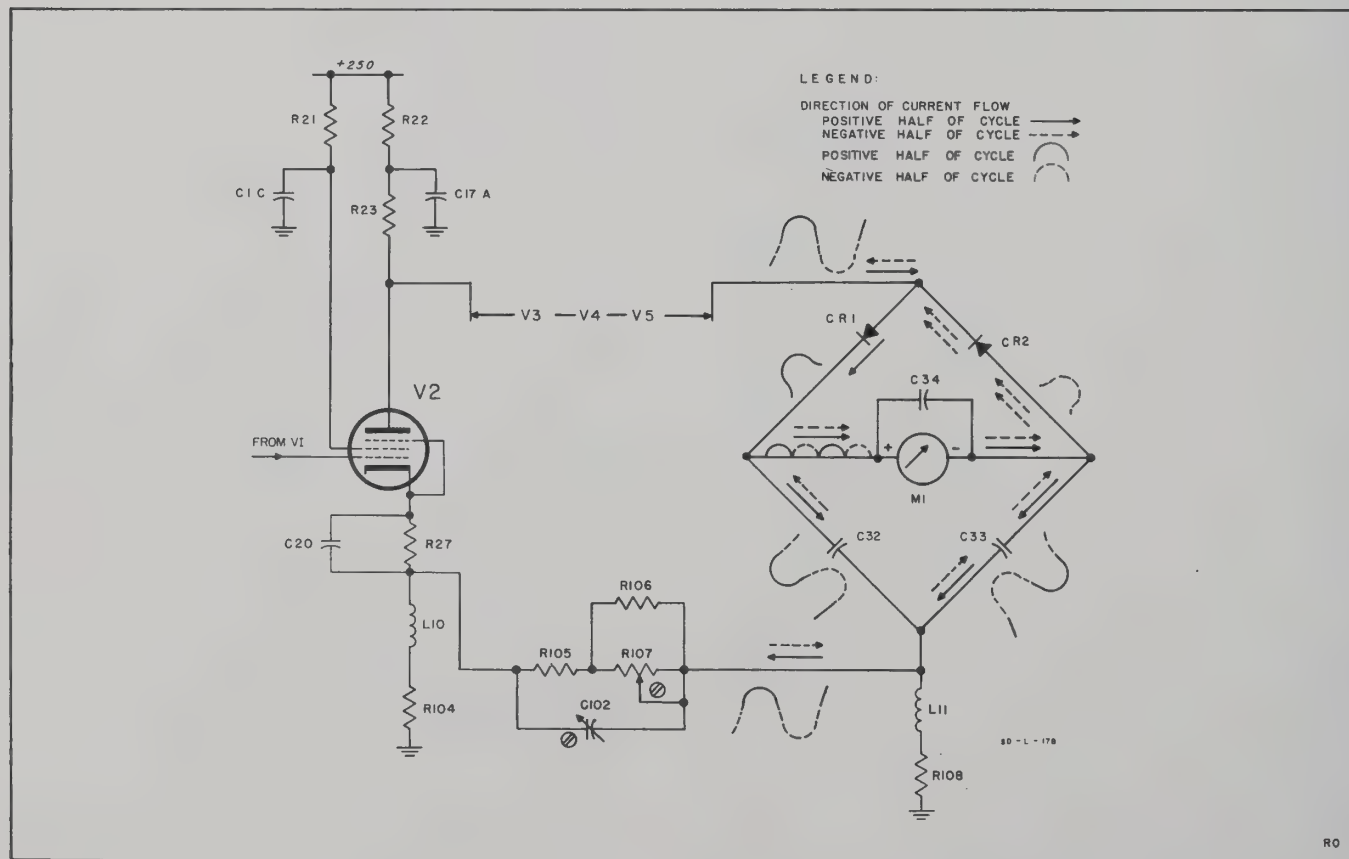


Figure 4-2. Simplified Schematic of Meter Bridge Circuit

to within ± 1 volt dc as the V7 plate voltage is varied $\pm 10\%$, with about 60 ma of load current. The response of the regulating circuits is fast enough to reduce ripple in the output voltage to less than 1 millivolt, supplementing the filtering action of C30. C36 couples the ripple component in the regulated output directly to V8B to avoid attenuation in R62. R57 shunts a small portion of the load current around V7 to prevent excessive V7 plate dissipation at high line voltages. R63 and C35 constitute a low-pass filter which prevents noise generated in V9 from reaching V8B.

4-17. The heater supply for the voltmeter tubes is divided into two sections. One section supplies d-c voltage for the tubes in the input cathode follower and

the amplifier. The other section supplies a-c voltage for the tubes in the power supply. The voltage required for the heaters of tubes V1 through V4 is obtained from 6.3V and 7.3V secondary windings of transformer T1, which are series connected. The voltage developed across the two series-connected windings is rectified by full-wave rectifier CR3, reduced to 12.6 volts by R66 and R68 in parallel, and applied to the series-parallel-connected heaters of V1 through V4, as shown in figure 5-10. The series-parallel connection of the four heaters establishes a voltage of 6.3V for each. The heater of V5 receives 6.3V ac from one of the windings which drives CR3. The heaters of V6, V7, and V8 receive 6.3V ac from a separate 6.3V secondary winding on T1.

SECTION V

MAINTENANCE

5-1. SCOPE.

5-2. This section contains complete instructions for repairing and calibrating the voltmeter. This material is covered in the following groups of paragraphs:

Lead Paragraph	Topic
5-3.	Precautions
5-5.	Test Equipment Required
5-7.	Meter Zero Adjustment
5-9.	Cabinet Removal
5-10.	Tube Replacement
5-13.	Replacement of Special Parts
5-17.	Trouble Shooting
5-20.	Testing the Power Supply
5-22.	Testing Voltmeter Performance
5-24.	Calibration and Frequency Response Adjustments

5-3. PRECAUTIONS.

5-4. Observe the following precautions:

a. Make no adjustments and replace no parts in the voltmeter except as described in one of the following

procedures. If an adjustment or replacement of parts is made without following instructions or understanding the effects, further trouble shooting may be complicated.

b. Do not remove tubes when the voltmeter is turned on. Before replacing tubes refer to paragraph 5-10.

5-5. TEST EQUIPMENT REQUIRED.

5-6. The test equipment required for complete testing of the voltmeter is listed in figure 5-1. Equivalent instruments may be substituted for those listed.

5-7. METER ZERO ADJUSTMENT.

5-8. The meter is properly zero-set when its pointer rests over the zero calibration mark on the meter scale when the instrument is 1) at normal operating temperature, 2) in its normal operating position, and 3) turned off. Adjust the zero-set if necessary, as follows:

a. Allow the voltmeter to operate for 20 minutes so that the meter movement will reach normal operating temperature.

b. Turn the voltmeter off and allow one minute for all capacitors to discharge.

INSTRUMENT TYPE	REQUIRED CHARACTERISTICS	USE	DESIGNATION
Electronic Multimeter	0 to 300 a-c and d-c volts; accuracy of $\pm 3\%$ or better; input impedance 100 megohms.	Voltage and resistance measurement.	ME-26B/U or H-P 410B
Oscillator	10 cps to 300 kc; 3 volts output into 50-ohm load.	Signal source for testing and calibration	H-P 200S
Voltmeter Calibrator (Precision Voltage Source)	400-cps output voltage; 0.001 to 300 volts in 10-db steps $\pm 0.2\%$; 0.1 to 1.0 volt in 0.1 volt steps $\pm 0.2\%$.	Calibrating voltmeter at mid-frequencies.	H-P 738BR
Frequency Response Test Set	300-kc to 4-mc range; 3 volts output into 50-ohm load; 10-db steps, 0 to 70 db.	Calibrating voltmeter frequency response.	H-P 739A
Oscilloscope or AC Voltmeter	10-cps to 4-mc range.	Trouble shooting by signal tracing.	H-P 160B or H-P 400D
Variable Transformer	Adjust line voltage between 103 and 127V ac with 1-amp load.	Checking voltmeter operation with varying line voltage.	CN-16/U or Ohmite VT2
D-C Current Test Set (Milliammeter)	Clip-on type measurement; current range up to 100 ma.	Checking load on power supply.	H-P 428B

Figure 5-1. Test Equipment Required

c. Rotate mechanical zero-adjustment screw clockwise until meter pointer is to the left of zero and moving upscale toward zero.

d. Continue to rotate adjustment screw clockwise; stop when pointer is exactly on zero. If pointer overshoots zero, repeat steps c and d.

e. When pointer is exactly on zero, rotate adjustment screw approximately 15 degrees counterclockwise. This is enough to free the zero adjustment screw from the meter suspension. If pointer moves during this step, because the adjustment screw is turned too far counterclockwise, repeat the procedure of steps c through e.

5-9. CABINET REMOVAL.

a. Remove the two cabinet retaining screws at the rear of the instrument.

b. Push the instrument chassis forward out of the cabinet. The bezel ring remains attached to the front panel.

c. When replacing cabinet, pull power cable through opening at rear of cabinet. Be sure power cable is not caught between chassis and cabinet. Replace retaining screws.

5-10. TUBE REPLACEMENT.



Do not remove tubes from the voltmeter when power is applied. To do so may damage the voltmeter.

5-11. In many cases instrument malfunction can be corrected by replacing a weak or defective tube. Check tubes by substitution while following the voltmeter

performance check procedure in paragraph 5-22. Results obtained through the use of a "tube checker" can be misleading. Before removing the tubes from the instrument, mark the original tubes so they can be returned to the same socket if they are not defective. Replace only those tubes proven to be defective.

5-12. Figure 5-2 lists each tube in the voltmeter with its function and the check or adjustment required if the tube is replaced.

5-13. REPLACEMENT OF SPECIAL PARTS.

5-14. PRECISION RESISTORS AND INDUCTORS. Several parts used in the voltmeter have closer tolerances than those used in most test equipment. Resistors R104, R105, R108, and R111 through R116 are precision components. If these resistors require replacement, use the same value and type as the original, as shown in the parts breakdown. If different values are used or component positions are moved, the calibration of the voltmeter may be inaccurate or the frequency response may be altered. The inductance of L10 and L11 affects the frequency response of the voltmeter. Do not alter the shape or position of these coils. Install replacement components in the same positions the original components occupied, as nearly as possible.

5-15. DIODE RECTIFIERS. Special high-performance silicon diodes selected by the Hewlett-Packard Co. are used for CR1 and CR2. When replacing the silicon diodes, be careful in soldering; heat can damage them. Place a heat sink (such as a long-nose pliers) on each diode lead close to the diode body to conduct the heat away. If CR1 and CR2 are replaced, the voltmeter calibration and frequency response must be checked as described in paragraph 5-22.

5-16. RANGE SWITCH. Because of the critical construction and wiring of switch S1, it is not practical to attempt a major repair on the switch. When mechanical failure occurs in switch S1, replace the complete

CIRCUIT REF.	TYPE	FUNCTION	CHECK OR ADJUSTMENT
V1	6CB6*	Cathode Follower	Calibration and frequency response (para. 5-22)
V2	6CB6	1st Amplifier	
V3	6CB6	2nd Amplifier	
V4	6CB6	3rd Amplifier	
V5	6CB6	4th Amplifier	
V6	6AX5	High Voltage Rectifier	Test of the power supply (para. 5-20)
V7	12B4A	Series Regulator	
V8	6U8	Control Tube	
V9	5651	Reference Tube	
* Note that V1 must be replaced by a 6CB6, aged and selected for low noise and microphonics (t_{hp} , Part No. 5080-0621).			

Figure 5-2. Adjustments Required When Tubes Are Replaced

switch assembly. Use the following procedure. (Locate parts by referring to figures 5-3 and 5-4; RANGE switch connections are shown in figure 5-9.)

- a. Remove voltmeter cabinet. (See paragraph 5-9.)
- b. Loosen setscrews in RANGE switch knob and remove knob.
- c. Disconnect capacitor C104 from switch S1.
- d. Disconnect white leads from capacitors C14 and C16. Label each lead with a tag.
- e. Remove the two screws and one nut which retain the switch shield plate.
- f. Disconnect white leads from switch contacts. Tag each lead to permit easy connection to the new switch.
- g. Disconnect the heavy dark-green switch lead, the heavy light-green switch lead, and the heavy black switch lead at terminal strips. Tag each lead.

NOTE

The input shield must be removed for access to the terminal board connection of the dark-green lead.

- h. Remove the nut which holds the switch bushing to the front panel.
- i. Remove RANGE switch assembly.
- j. The sequence for installing the replacement RANGE switch assembly is the reverse of the removal procedure.
- k. After replacement of switch S1, check the calibration and frequency response of the voltmeter and make necessary adjustments.

5-17. TROUBLE SHOOTING.

5-18. The first step in trouble shooting is to learn the nature of the symptoms of the malfunction with as much detail as possible. Inspect the test setup being used when symptoms of malfunction were observed, to be sure that the source of trouble is not external to the voltmeter. Then remove the voltmeter cabinet as directed in paragraph 5-9 and inspect the circuits of the voltmeter, looking for signs of overheating, deterioration, and physical damage or tampering. Check the fuse. If the fuse is blown, try another fuse to see if it blows; if it does, measure the d-c resistance of filter capacitors C1, C17, C30, C39, rectifier CR3, and the windings of transformer T1 to locate the short circuit without applying power to the voltmeter.

5-19. If the voltmeter can be turned on safely (without the fuse blowing), measure the line voltage applied to T1 and the voltmeter power supply output voltages (see paragraph 5-20). Check the tubes of the power supply if the regulated voltage is not the proper value or is unstable. Use the procedures of figure 5-5 and the tests described in paragraph 5-22 to learn the full nature of the trouble symptom. Watch for marginal

operation by operating the voltmeter at 103 and 127 line volts while making tests. Check the tubes in the voltmeter amplifier. Measure the tube element voltages at the tube sockets and compare readings with the values shown in the voltage and resistance diagram in figure 5-8. Apply a test signal to the input and measure the voltage of the test signal while tracing it through each coupling network and each stage of amplification. Compare readings with those shown in the block diagram, figure 4-1. In figure 4-1, an a-c current probe, H-P Model 456A, is recommended for the measurement of a-c current in the meter circuit without breaking any leads. If this current probe is not available, avoid measurement of the a-c current. Check meter indications as directed in paragraph 5-22 instead. An oscilloscope may be used for observing test signal waveshape and measuring amplitude, if desired.

5-20. TESTING THE POWER SUPPLY.

5-21. The regulated power supply produces a constant +250 vdc to operate all the tubes in the amplifier section. The stability of the voltmeter depends directly upon the stability of the +250 volts from the supply. When the supply is operating satisfactorily, the +250 volt output remains constant and the ripple level on it remains less than about 1 millivolt for line voltages between 103 and 127 volts. Weak tubes (V6, V7, and V8) are the usual causes of instability. An unstable regulator tube is indicated by excessive line frequency ripple and varying output voltage as the line voltage is changed. Marginal operation is indicated if a trouble symptom appears only when a low or high line voltage is applied. To test the complete power supply proceed as follows:

- a. Connect the voltmeter to an adjustable line transformer so the applied line voltage can be varied between 103 and 127 volts. Set line voltage to 115 volts, turn on the voltmeter, and allow a five-minute warmup period.
- b. Measure the d-c voltage between V6 (pin 8) and ground. Normal value is 410 ± 10 volts with exactly 115 volt power line input. Lower line voltage 10% to 103 volts for 2 minutes. If the d-c voltage slowly drops below 360 volts, replace V6.
- c. Measure the d-c voltage between V7 (pin 1) and ground with line voltage adjusted to 115 volts. Correct value is 250 ± 5 volts.
- d. Vary line voltage from 103 to 127 volts. The d-c voltage observed in step c must not change more than ± 1 volt. For wrong voltage and/or poor regulation, replace V7, V8 or V9.
- e. Measure the a-c voltage between V7 (pin 1) and ground. Ripple voltage must be less than 3 mv for any line voltage (103 to 127 volts). High ripple voltage is caused by defective V8, V7, V6 or V9. Replace in this order.
- f. Measure the direct current in the lead from V7 (pin 1) which must be less than 60 milliamperes. If the current is much too high, the regulator circuit will not function properly. Excessive current indicates

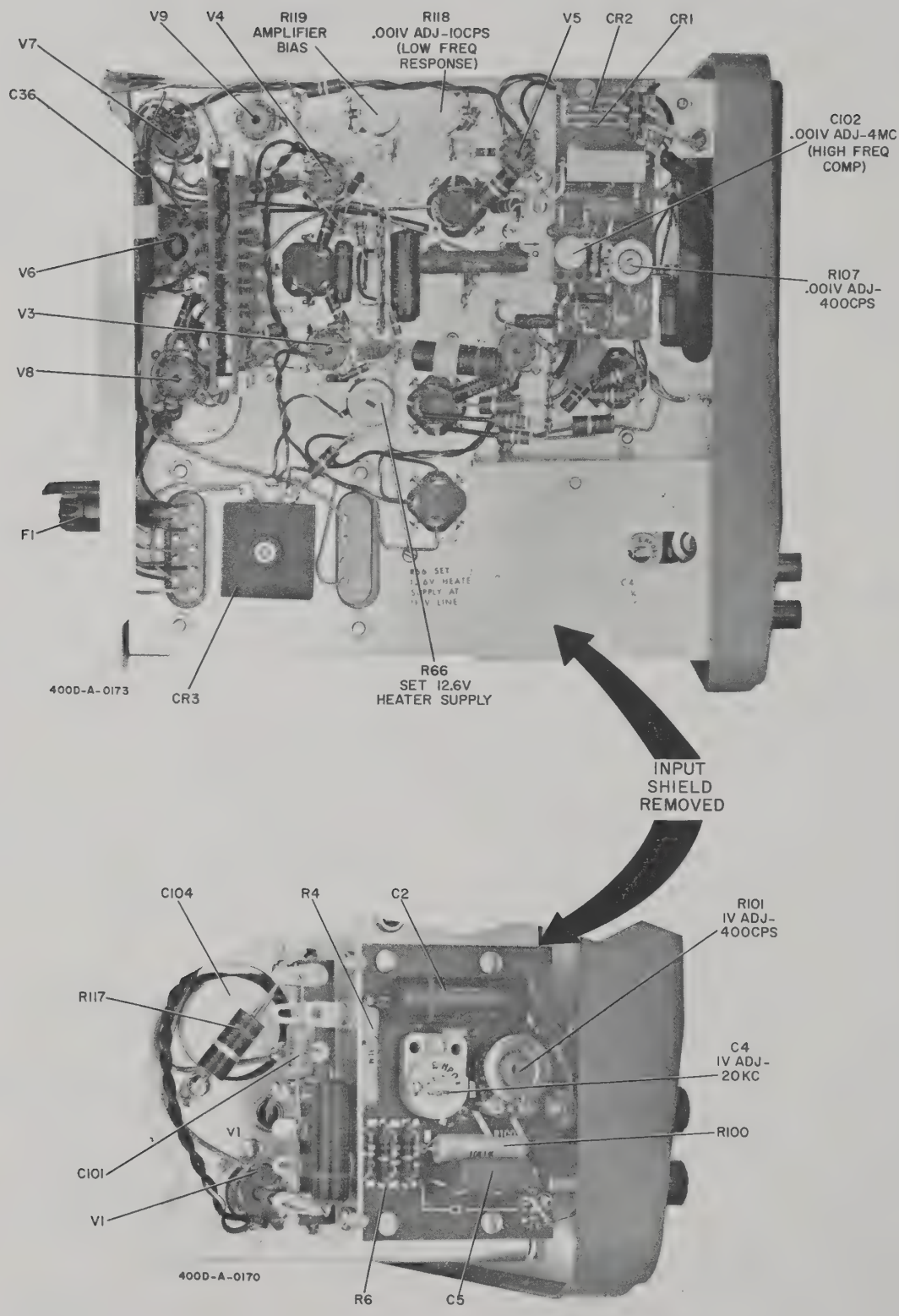


Figure 5-3. Left Side View of Voltmeter Chassis

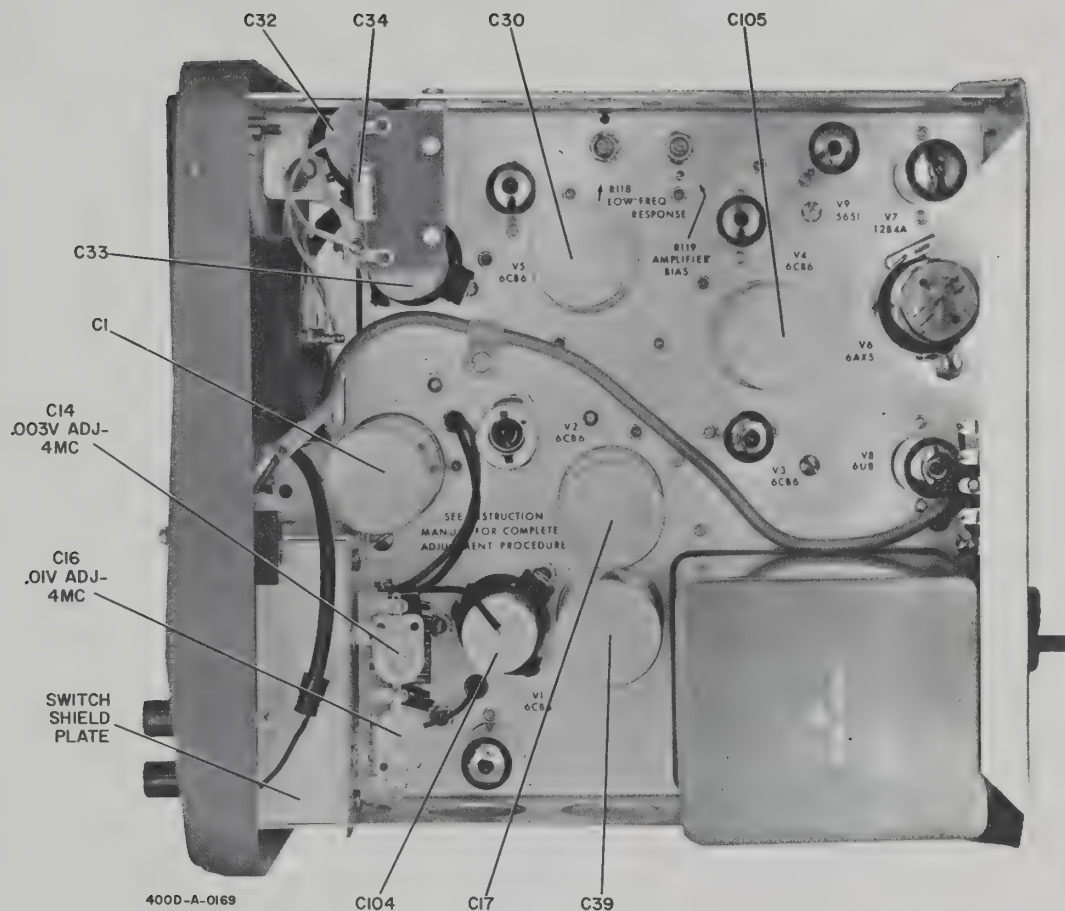


Figure 5-4. Right Side View of Voltmeter Chassis

a short circuit or partial short in the circuits of the voltmeter amplifier section. A clip-on type milliammeter should be used for this measurement.

g. If the output voltage is stable but is incorrect, measure the resistance of R62 and R64. The ratio of these two resistors determines what the output voltage will be. If the value of one of these resistors is incorrect and produces the wrong output voltage, replace it with a resistor which provides the correct output voltage.

h. Measure the d-c voltage across C39A which must be 12.6 volts with a line voltage of 115 volts. If necessary, adjust R66 to obtain 12.6 volts. If the voltage cannot be set to 12.6 volts, check the a-c voltage from the associated transformer windings; also check CR3 and C39.

5-22. TESTING VOLTMETER PERFORMANCE.

5-23. The following test procedure checks the accuracy and stability of the voltmeter at low and high frequencies

and with low and high line voltages. It can be used for comprehensive incoming inspection, for proof of performance, and for trouble shooting. If the readings are within specifications during these tests, the voltmeter is operating properly. This test is made without removing the cabinet. Instruments used to test the accuracy of the voltmeter (see paragraph 5-5) must be known to have sufficient accuracy to make valid measurements. Proceed as follows:

a. Connect the voltmeter as shown in figure 5-6. (This setup measures calibration accuracy at mid-frequencies.)

b. Set the line voltage to 115 volts, turn the voltmeter on and allow a 30-minute warmup period.

c. Check the instrument meter zero setting as instructed in paragraph 5-7.

d. Connect the voltmeter to the voltmeter calibrator; set voltmeter RANGE switch to .001, and set voltmeter calibrator VOLTAGE SELECTOR switch to provide 0 volts output.

TROUBLE	PROBABLE CAUSE	REMEDY
1. Power indicator lamp does not light.	a. Fuse F1 burned out. b. Power indicator lamp DS1 defective. c. Defective a-c power cable. d. Power switch S2 defective. e. Transformer T1 primary winding terminals incorrectly connected.	a. Replace fuse F1. If replaced fuse blows, check items 2 and 3 below. b. Replace power indicator lamp DS1. c. Repair or replace power cable. d. Replace Power switch S2. e. Check connections of transformer T1 primary winding; rewire if necessary.
2. Fuse F1 blows immediately when Power switch S2 is operated to ON.	a. Tube V6 shorted. b. Rectifier CR3 defective. c. Short circuit in transformer T1 or in circuit wiring.	a. Replace rectifier tube V6. b. Replace heater rectifier CR3. c. Remove all tubes, and check transformer windings. Replace transformer T1 if defective. Check for short circuit.
3. Fuse F1 blows after Power switch S2 has been operated to ON and tube heaters have warmed up.	Short in power supply circuit.	Check for short circuit at cathodes V6 and V7. Replace defective component.
4. Power indicator lamp lights; voltmeter does not indicate on all ranges.	a. Power supply or voltage regulator circuits defective. b. Rectifier CR3 or circuit component defective. c. Diode CR1 or CR2 defective.	a. Check tubes V6, V9, V7, and V8 in turn. Check high-voltage winding of transformer T1. Replace defective component. b. Check for 12.6 volts dc across output of rectifier CR3. Check resistors R66 and R68. If tubes V1 and V2 are not lighted, check capacitor C39. Replace defective component. c. Replace diode (paragraph 5-15).
5. Meter indication normal on low ranges (.001 to .3 volts). Meter sensitivity distorted on high-voltage ranges (1 to 300 volts).	Compensated 1000:1 divider defective.	Check C4 and R4. Replace defective component.
6. Meter indicates low on all ranges.	a. Low amplifier gain. b. Diode CR1 or CR2 defective.	a. Check B+ voltage (paragraph 5-20). Check tubes V2 through V5 for low emission. If any tube is replaced, check and recalibrate the voltmeter (paragraph 5-22). b. Replace diode (paragraph 5-15).
7. Meter indication unstable or erratic.	a. Power supply, circuit defective. b. Amplifier tube V1, V2, V3, V4, and V5 defective.	a. Check heaters and B+ voltage. Replace defective component. b. Check V1 through V5 for microphonics or noise. If tube is replaced, check and recalibrate the voltmeter (paragraph 5-22).
8. Meter indication normal on .001 and 1 volt range. Meter sensitivity distorted on all other ranges (.003, .01, .03, .1, .3, 3, 10, 30, 100, and 300 volts).	Faulty RANGE switch S1.	Check switch contacts of S1. Replace RANGE switch S1 if defective (paragraph 5-16).

Figure 5-5. Trouble-Shooting Procedure

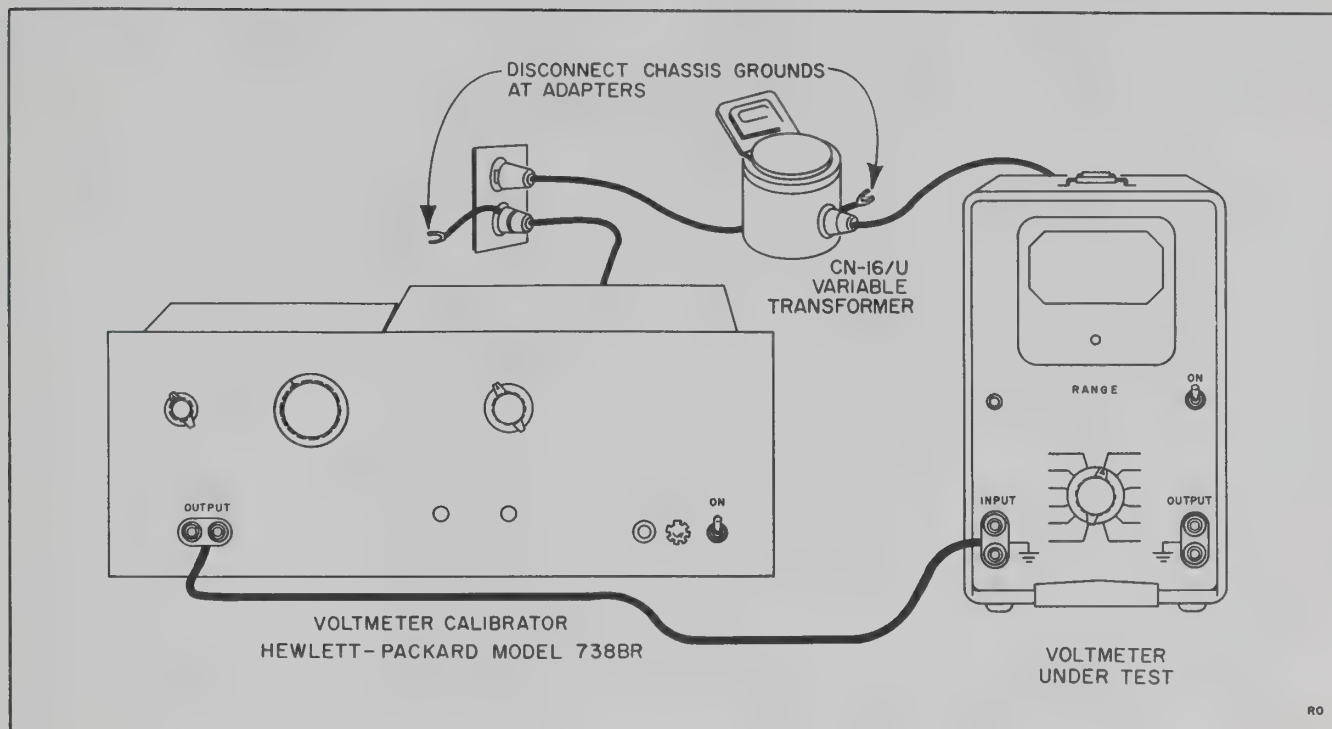


Figure 5-6. Test Setup for Calibration Check and Adjustments

The residual reading on voltmeter must be no higher than the residual reading obtained with voltmeter INPUT terminated with a 10-megohm resistor and shielded to prevent stray pickup. If the residual reading is higher when connected to the calibrator, refer to paragraph 3-12.

e. Set the voltmeter RANGE switch to .001. Set the voltmeter calibrator to provide .001 volt rms (400 cps) output. Record deviation of voltmeter reading from 1 on the voltmeter scale.

f. Set the voltmeter RANGE switch to 1. Set the voltmeter calibrator to provide 1 volt rms output. Record deviation of voltmeter reading from 1 on the voltmeter scale.

g. Still using the voltmeter 1-volt range, reduce the voltmeter calibrator output in 0.1 volt steps. Record deviation of voltmeter readings from each 0.1 volt calibration mark.

h. Compare recorded deviations with the permissible errors listed in the performance specifications in figure 1-2.

i. Connect the voltmeter as shown in figure 5-7 and set line voltage to 115. (This setup measures calibration accuracy at low and high frequencies.)

j. Set voltmeter RANGE switch to .001. Set frequency response test set OUTPUT ATTENUATOR to .001 to measure the lowest voltmeter range; initially set AMPLITUDE control for 0 volts output. Then note volt-

meter reading; it must not be higher than the residual reading noted in step d.

k. Turn the frequency response test set RANGE SELECTOR to EXTERNAL. Set the external oscillator frequency to 400 cps; adjust the oscillator output level to obtain a reading of .9 on the 0 to 1 VOLTS scale of the voltmeter. Then adjust the METER SET control on the frequency response test set to obtain a standard meter indication at the SET LEVEL mark on the test set meter.

l. Tune the external oscillator to 10 cps and adjust its output level to keep the frequency response test set meter reading at SET LEVEL. Do not adjust the METER SET control as this would alter the fixed monitoring point of the meter. Record the voltmeter deviation from .9 on the scale. This reading must be between 0.85 and 0.95 to be within specifications.

m. Set the RANGE SELECTOR on the test set to 3-10 mc, set the FREQ. TUNING dial to 4, and adjust the AMPLITUDE control to keep the frequency response test set meter reading at SET LEVEL. Record the voltmeter deviation from .9 on the scale. This reading must be between 0.85 and 0.95 to be within specifications. The gain and frequency response of the basic voltmeter amplifier is now tested.

n. Repeat step m using line voltages of 103 and 127. Record voltmeter deviation from .9 on the scale.

o. Set voltmeter RANGE switch to .003 and also set the frequency response test set OUTPUT ATTENUATOR to .003 to check this voltmeter range. Repeat steps k and m. Record voltmeter deviation from .9 on the scale.

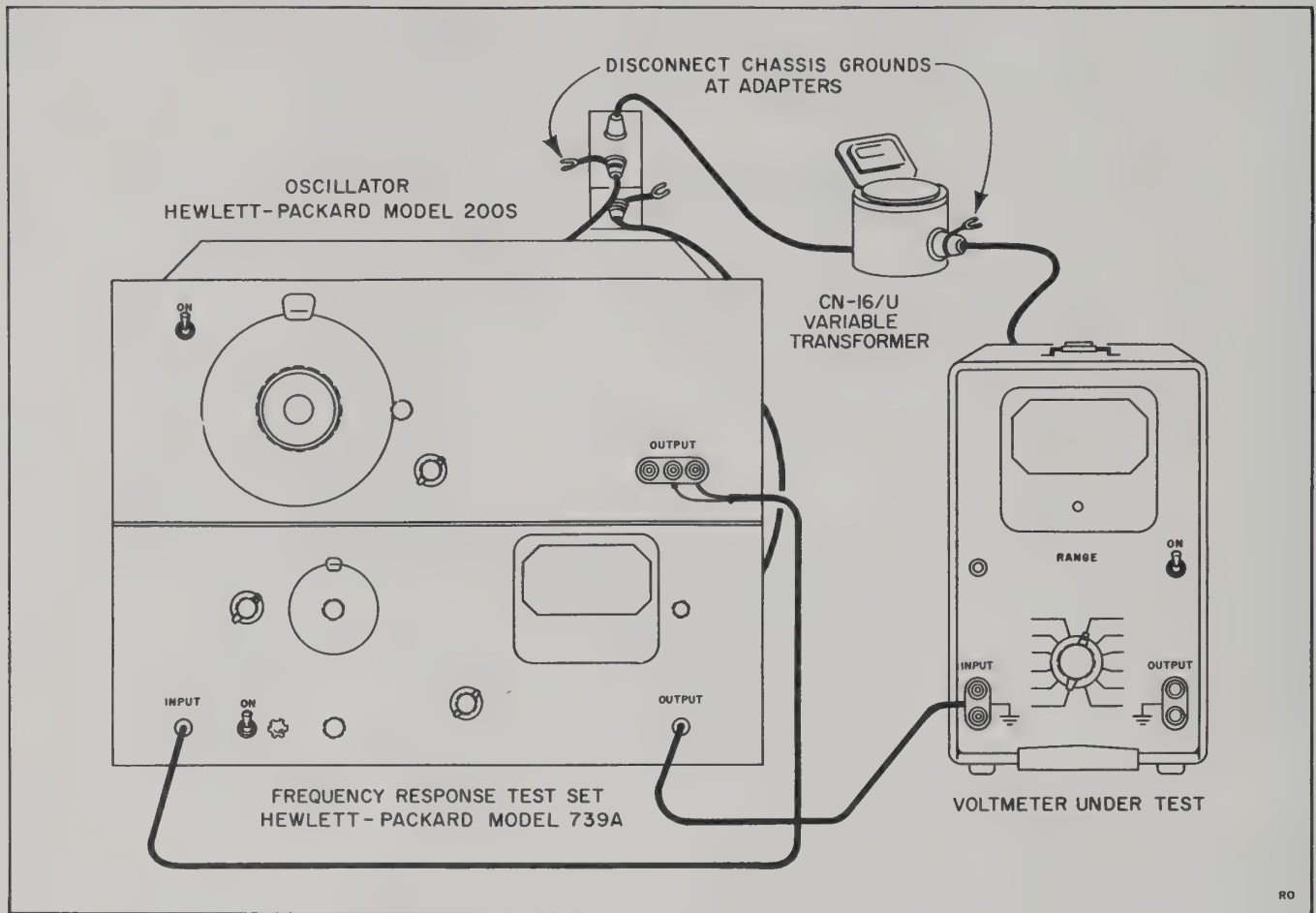


Figure 5-7. Test Setup for Frequency Response Check and Adjustment

p. Set voltmeter RANGE switch to .01 and also set the frequency response test set OUTPUT ATTENUATOR to .01 to check this voltmeter range. Repeat steps k and m. Record voltmeter deviation from .9 on the scale.

q. Set voltmeter RANGE switch to 1 and also set the frequency response test set OUTPUT ATTENUATOR to 1. Repeat step k.

r. Turn the frequency response test set RANGE SELECTOR to EXTERNAL. Set external oscillator frequency to 20 kc and adjust output level to keep the frequency response test set meter reading at SET LEVEL. Record voltmeter deviation from .9 on the scale.

s. Repeat step m and record voltmeter deviation from .9 on the scale.

t. The voltmeter is now completely tested. If the measurements made have shown the voltmeter reading to be within the tolerances given in the performance specifications in Section I, the voltmeter is operating satisfactorily. If operation is unsatisfactory, make calibration and frequency response adjustments as directed in paragraph 5-24.

5-24. CALIBRATION AND FREQUENCY RESPONSE ADJUSTMENTS.

5-25. Calibration and frequency response adjustments may be required when components other than those in the power supply circuit are replaced. After replacing any of these components, carry out the voltmeter performance test of paragraph 5-22 to see if adjustments are necessary. If the voltmeter operates within specifications during the test of paragraph 5-22, with respect to both calibration (at mid-frequencies) and frequency response, no adjustments are needed. If operation at mid-frequencies meets calibration specifications, only the frequency response adjustments need be made. Otherwise, make all calibration and frequency response adjustments in the order listed in the following procedure.

5-26. Calibration of the voltmeter consists of five parts:

- Setting the basic gain of the amplifier at 400 cps.
- Setting the division ratio of the input attenuator at 400 cps.
- Setting the frequency response of the amplifier.
- Setting the 4-mc frequency response of the step attenuator.

e. Setting the 20-kc and 4-mc frequency response of the input divider.

NOTE

It is important to follow the complete procedure in the order given, instead of attempting individual adjustments which might appear to correct a certain fault in calibration.

5-27. Although a special voltmeter calibrator instrument and frequency response test set (listed in paragraph 5-5) are shown for calibrating the voltmeter, other precision a-c voltage sources having the required accuracy may be used for this calibration procedure. In the following procedure, the mechanical meter zero-set and the regulated B+ voltage must already be correctly set (see paragraphs 5-7 and 5-20, respectively). Proceed as follows:

a. Connect voltmeter calibrator and voltmeter under test as shown in figure 5-6. (Do not turn on.)

b. Provide a ground-level input to the voltmeter to check for stray pickup between the instruments by setting the voltmeter calibrator controls as follows:

OUTPUT SELECTOR to 400~RMS
RANGE SELECTOR switch to 1.5 - 5
VOLTAGE SELECTOR switch to 0
POWER switch to ON

c. Set the RANGE switch on the voltmeter under test to .001 volt, and the Power switch to ON. Allow at least a ten-minute warmup. Refer to paragraph 3-12 of this manual and to the manual for the Model 738BR Voltmeter Calibrator for a procedure to test for ground currents. Eliminate any ground currents by breaking ground loops as directed in paragraph 3-12.

d. To test the .001 volt range, set the voltmeter calibrator to .001 volt and the voltmeter RANGE switch to .001. If necessary, adjust R107 (figure 5-3) to obtain a reading of exactly 1 on the 0 to 1 VOLTS scale on the panel meter of the voltmeter under test. This sets the gain of the amplifier at audio frequencies.

e. Set the RANGE switch on the voltmeter to the 1-volt range. Set the voltmeter calibrator to 1 volt, to test this range. If necessary, adjust R101 (figure 5-3) to obtain a reading of exactly 1 volt on the voltmeter. This sets the division ratio of the input voltage divider at audio frequencies.

f. Connect the frequency response test set, the oscillator, and the voltmeter under test as shown in figure 5-7. Observe grounding precautions described in step c.

g. On the frequency response test set, set the OUTPUT ATTENUATOR to .001, the RANGE SELECTOR to EXTERNAL, and turn the Power switch ON. This adjusts the frequency response test set to provide an output from the external oscillator for the voltmeter .001-volt range.

h. Set the RANGE switch on the voltmeter under test to .001.

i. Set the oscillator for 400 cps output frequency and adjust its output level to obtain a reading at 0.9 on the voltmeter scale.

j. Adjust the frequency response test set METER SET control to obtain a meter reading at SET LEVEL on the test set. This standardizes the monitoring point of the output level.

k. Set the RANGE SELECTOR and FREQ. TUNING controls of the frequency response test set for 4-mc output frequency and adjust the AMPLITUDE control to provide a reading at SET LEVEL on the meter.

l. If necessary adjust C102 (figure 5-3) to obtain a reading at 0.9 on the voltmeter under test. This sets amplifier gain at video frequencies.

m. While watching voltmeter under test, adjust the frequency response test set FREQ. TUNING control from 4 to 10 Mc while holding output level constant with AMPLITUDE control. The frequency response curve increases from 4 to approximately 6 Mc and then drops off from approximately 6 to 10 Mc. The frequency response of instrument is within specification if voltmeter reading remains in 0 to 0.92 range. If not in specifications adjust R119 and repeat steps g through l.

NOTE

Whenever R119 is adjusted, both lo- and hi-freq. response is affected and must be retested.

n. Readjust oscillator and frequency response test set for 20 cps output and a SET LEVEL indication on the test set meter. If necessary adjust R118 (figure 5-4) to obtain a reading at exactly 0.9 on the voltmeter under test.

o. Repeat step n at a frequency of 10 cps, for a voltmeter reading between 0.85 and 0.95 ($\pm 5\%$). If 10 cps response is outside this range, readjust R118 slightly to bring 10 cps response within the specified limits.

p. Repeat the 400-cps to 4-mc frequency response check (steps g through k) on the .003 volt range of the voltmeter and if necessary adjust C14 (figure 5-4) to obtain a reading of 0.9 on the voltmeter at 4 mc.

q. Repeat the 400-cps to 4-mc frequency response check (steps g through k) on the 0.01 volt range of the voltmeter and if necessary adjust C16 (figure 5-4) to obtain a reading of 0.9 on the voltmeter at 4 mc.

r. On the 1-volt range of the voltmeter, measure frequency response at both 20 kc and 4 mc using a procedure similar to steps g through k. At 20 kc if necessary adjust C4 (figure 5-3) to obtain a reading of 0.9 on the voltmeter. At 4 mc if necessary pad the value of R6 (figure 5-3) to obtain a reading between 0.85 and 0.95 ($\pm 5\%$). R6 consists of several resistors connected in parallel. Increasing the value of one of these resistors raises the meter reading at 4 mc. The input shield must be in place on the voltmeter chassis when making this reading.

V7 (12B4)
SERIES REGULATOR
+120.0VAC
260K
+232
380K
+216
350K
+120.6.3VAC
260K
+225
400K
+245
54K
NC
+450
55K

V6 (6AX5)
HIGH VOLTAGE RECTIFIER
390VAC
150
NC
P₁
4 5 6
3 2 1
P₂
H
K
NC
+125
240K
+125, 6.3VAC
220K
+450
55K

V8 (6U8)
CONTROL TUBE
+125.0VAC
260K
+218
420K
+133
40K
+88
70K
+245
20K
+125.6.3VAC
240K
+133
40K
+88
70K
+245
20K
NC
P₁
4 5 6
3 2 1
P₂
H
K
NC
+125
240K
+125, 6.3VAC
220K
+450
55K

V9 (5651)
REFERENCE TUBE
NC
17-1-2
16-1-3
15-1-4
14-1-5
13-1-6
12-1-7
11-1-8
10-1-9
9-1-10
8-1-11
7-1-12
6-1-13
5-1-14
4-1-15
3-1-16
2-1-17
1-1-18
NC
+87
130K

V4 (6CB6)
3RD AMPLIFIER
+6.3
2.0
+12.6
3.8
+5.2
520
+3.5
100K
+115
75K
+143
100K
NC
P
4 5 6
3 2 1
H
K
Sp

V5 (6CB6)
4TH AMPLIFIER
0.5VAC
60
+5.6
560
+3.5
890
+131
68K
+136
100K
NC
P
4 5 6
3 2 1
H
K
Sp

V3 (6CB6)
2ND AMPLIFIER
+127
110K
+135
70K
+6.3
2.0
+3.5
1.2M
+4.9
525
+12.6
3.9
NC
P
4 5 6
3 2 1
H
K
Sp

V1 (6CB6)
INPUT CATHODE FOLLOWER
+170
70K
+6.3
2.0
+54
10.1M
+58
6600
NC
P
4 5 6
3 2 1
H
K
Sp

V2 (6CB6)
1ST AMPLIFIER
+110
130K
+115
30K
+6.3
2.0
+1.4
135
+1.4
135
+1.4
135
NC
P
4 5 6
3 2 1
H
K
Sp

Figure 5-8. Voltage and Resistance Diagram

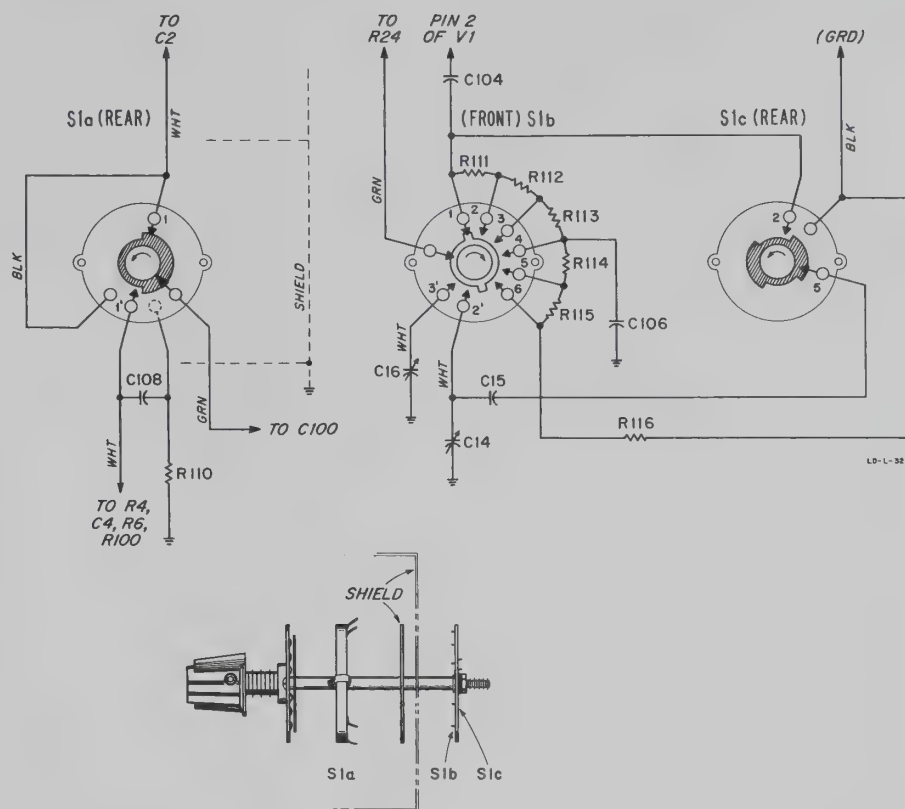


Figure 5-9. Diagram of RANGE Switch

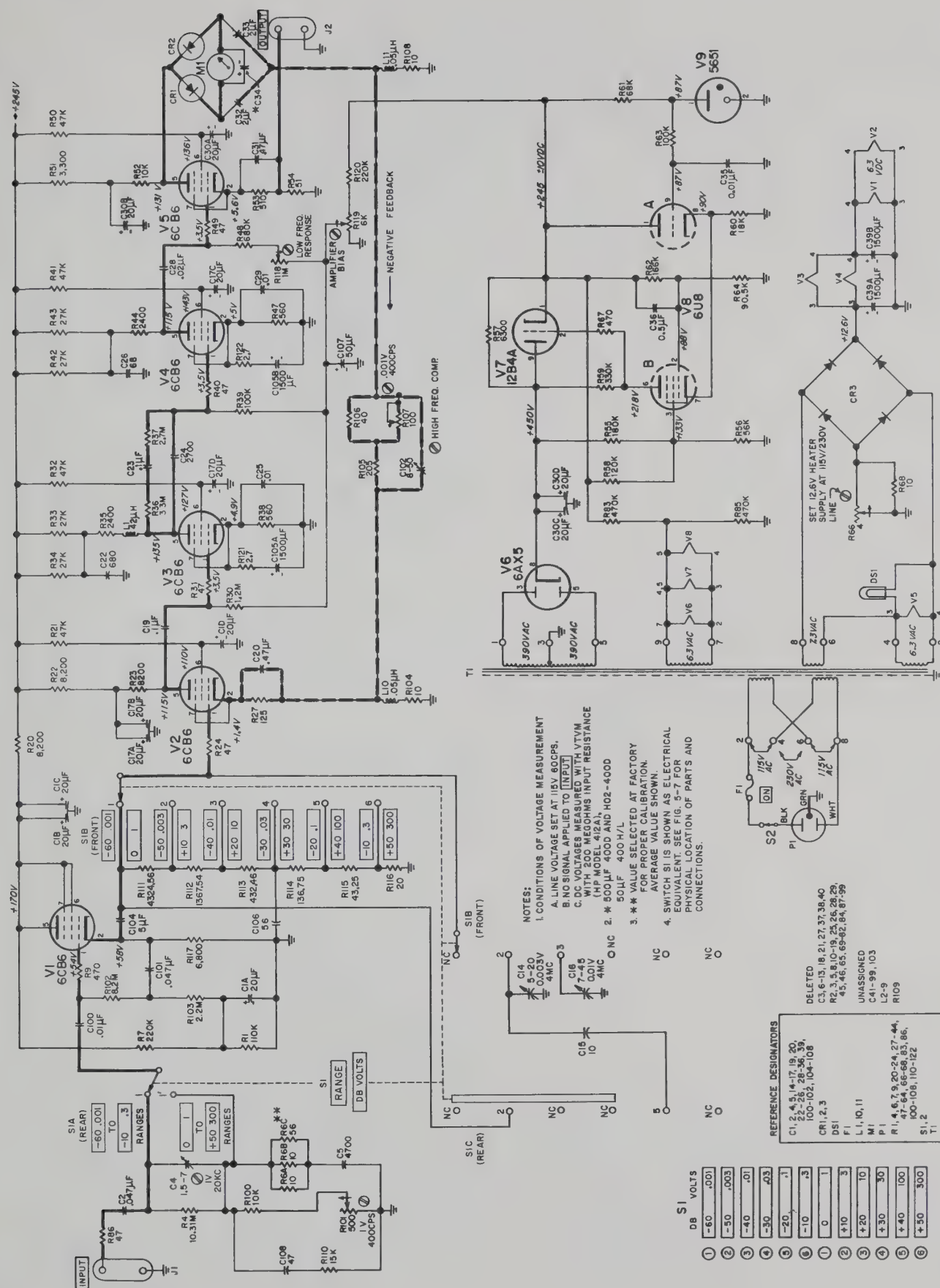


Figure 5-10. Voltmeter Schematic Diagram

SECTION VI

INTRODUCTION TO ILLUSTRATED PARTS BREAK DOWN

6-1. GENERAL.

6-2. This Illustrated Parts Breakdown lists and describes the parts applicable to the Vacuum Tube Voltmeters, Models 400D, 400H, 400L, and H02-400D, manufactured by Hewlett-Packard Co. The breakdown consists of four sections as shown in the Table of Contents.

6-3. GROUP ASSEMBLY PARTS LIST. The Group Assembly Parts List (Section VII) consists of the complete Voltmeter divided into six main assemblies or components as shown in the Table of Contents. Each assembly listed is followed immediately by its component parts indented to show relationship to the assembly.

6-4. Part numbers are used to identify parts. A MIL-type part number or a typical manufacturer and part number are listed for each vendor part in the Group Assembly Parts List. The actual part used may be supplied by a different vendor, but in all cases the Hewlett-Packard stock number remains the same. The H-P Stock No. column is adjacent to the manufacturer or military Part No. column.

6-5. The index numbers are numerically arranged in the Group Assembly Parts List and are used mainly to assist in locating a part in the Group Assembly Parts List after it has been found in the Numerical Indexes (Section VIII) or located on the figure which illustrates that particular assembly.

6-6. The nomenclature of each part in the Group Assembly Parts List is indented to indicate assembly relationship. Each part is indented one column to the right of the next higher assembly. When the details of an assembly are shown on a different figure and parts list, the nomenclature of that assembly is followed by a parenthetical note stating in which figure and parts list the details will be found.

6-7. Attaching parts are shown in the same indent as the parts which they attach, and immediately following the part. They are separated from the parts which they attach by the words (ATTACHING PARTS). The attaching parts are separated from the following assembly, or the details of the assembly which they attach, by the symbol ----*. When attaching parts are shown as attaching two or more parts, the quantities of the attaching parts are those required to attach the total number of the assemblies or parts being attached.

6-8. The quantities listed in the "Units per Assy" column of the Group Assembly Parts List are, in the case of assemblies, the total quantity used in the Voltmeter at the location indicated. In the case of component parts indented under the assembly, the quantity listed is the quantity used per assembly. The quantities specified in any one entry, therefore, are not necessarily the total used per complete Voltmeter. Refer to the Numerical Indexes (Section VIII) for the total quantities used per complete voltmeter.

6-9. USABLE ON CODE. Part variations within the voltmeters are indicated by a letter symbol or combination of letter symbols in parentheses immediately following the figure and index number in the same column. An explanation of the symbols used is outlined below. In cases where the "Usable on Code" column has been left blank, parts listed apply to all models covered by this book.

USABLE ON CODE	MODEL NUMBER
D	400D
H	400H
L	400L
H02	H02-400D

6-10. PART NO. NUMERICAL INDEX. The Part Number Numerical Index (Section VIII) is compiled in accordance with the numerical part number filing system described below:

a. Part number numerical arrangement starts at the left-hand position of the part number and continues from left to right, one position at a time, until part number numerical arrangement is determined for all the part numbers. In the Part No. Numerical Index the federal stock number consists of a class code prefix followed by a serial number or the part number; that is, when a serial number has been assigned, the class code and serial number form the stock number; when a serial number has not been assigned, the class code and part number form the federal stock number.

b. The order of precedence in the arrangement of the part number is as follows:

- (1) Space (blank position in the number)
- (2) Dash (-)
- (3) Letters A through Z
- (4) Numerals 0 through 9
Alphabetical O's shall be considered as numerical zeros

6-11. In cases where the same part appears in several assemblies and therefore has several different figure and/or index numbers, the Part No. Numerical Index lists the figure and index number of each appearance, and the total quantity of the part used is given on the line with the first figure and index number entry.

6-12. HEWLETT-PACKARD STOCK NO. INDEX. The Hewlett-Packard Stock No. Index is a numerical index of Hewlett-Packard stock numbers, arranged in alphabetical form in the same manner as the Part No. Numerical Index. The Hewlett-Packard Stock No. Index follows the Part No. Numerical Index in Section VIII.

6-13. REFERENCE DESIGNATION INDEX. The Reference Designation Index (Section IX) lists electrical parts by reference designator and is compiled with reference designators in alpha-numerical order. It provides a convenient method for locating parts within the Group Assembly Parts List when the reference designator is known.

6-14. SOURCE CODING. Source coding as applied to the Numerical Indexes has been assigned by Department representatives.

SOURCE CODE DEFINITIONS

a. CODE "P" - PARTS UNDER INVENTORY STOCK CONTROL

(1) CODE "P" is applied to the parts which are procured in view of relatively high usage. Code "P" parts may be requisitioned and installed by any maintenance level, unless followed by the letter - "O", which restricts requisition and replacement to Depot (O&R) level only. Restricted service manufacture is considered practicable but only after an attempt has been made to procure from Supply Sources. In lieu of the procurement of "P" coded parts, the Department may designate a Depot (O&R) level activity to manufacture supply requirements for the Program.

(2) CODE "P1" is applied to parts which are very difficult or uneconomical to manufacture. Service manufacture is considered impracticable. Code "P1" parts may be requisitioned and installed by any maintenance level, unless followed by the letter - "O" which restricts the requisition and replacement to Depot (O&R) level only.

b. CODE "M" MANUFACTURE, PARTS NOT PROCURED

(1) CODE "M" is applied to parts which are within the facilities of any activity to manufacture. Procurement and stocking are not justified in view of the relatively low usage, or storage and installation factors, of these parts. Needs are to be met by local manufacture as required.

(2) CODE "M1" is applied to parts which can be manufactured only by utilizing the facilities of the Depot (O&R) activity. Procurement and stocking of these parts are not justified in view of their relatively low usage and installation factors. The needs of all activities are to be met through salvage, or by Depot (O&R) level manufacture.

c. CODE "A" ASSEMBLE - ASSEMBLY NOT PROCURED

(1) CODE "A" is applied to assemblies made up of two or more units each of which carry individual part numbers and descriptions, and which may be assembled by any maintenance level.

(2) CODE "A1" is applied to assemblies made up of two or more parts each of which carry individual part numbers and descriptions, and which may be assembled only by activities having Depot (O&R) facilities.

d. CODE "X" PARTS CONSIDERED IMPRACTICABLE FOR MANUFACTURE OR PROCUREMENT

(1) CODE "X" is applied to the Main Structural Members or similar parts which, if required, would suggest extensive aircraft or equipment reconditioning. The need of a part, or parts, coded "X" (wing spar caps, center section structure) should normally result in a recommendation to retire the aircraft or equipment from Service.

(2) CODE "X1" is applied to parts for which the procurement of the next larger assembly is justified; e.g., an integral detail part, such as welded segments, inseparable from its assembly; a part machined in a matched set; or a part of an assembly which, if required, would suggest extensive reconditioning of each assembly.

(3) CODE "X2" is applied to parts which are neither procured nor stocked. Activities requiring such parts shall attempt to obtain from salvage; if not obtainable from salvage, such parts shall be requisitioned through normal supply channels with supporting justification.

e. CODE * PARTS NOT PROCURED, MANUFACTURED OR STOCKED

(1) CODE * applies to installation drawings, diagrams, instructions or field service drawings, basic drawing numbers which cannot be procured or manufactured, and obsolete parts.

6-15. VENDOR'S CODE. Vendor's code numbers have been assigned in accordance with Federal Supply Code H-4-1. The vendor's code appears in parentheses following the item name or within the description of each item in the Group Assembly Parts List (Section VII). The vendor's codes used in this Illustrated Parts Breakdown are listed below for convenience.

VENDOR'S CODE

CODE	NAME AND ADDRESS
04009	Arrow, Hart, and Hegeman Electric Co., Hartford, Conn.
14655	Cornell Dubilier Electric Corp., South Plainfield, N.J.
14674	Corning Glass Works, Corning, N.Y.
19701	Electra Mfg. Co., Kansas City, Mo.
24446	General Electric Co., Schenectady, N.Y.

CODE	NAME AND ADDRESS	CODE	NAME AND ADDRESS
28480	Hewlett-Packard Co., Palo Alto, Calif.	83330	Smith, Herman H., Inc., Brooklyn, N.Y.
28520	Heyman Mfg. Co., Kenilworth, N.J.	83380	Buckley, C.E., Leominster, Mass.
35434	Lectrohm, Inc., Chicago, Ill.	84411	Good All Electric Mfg. Co., Ogalala, Nebr.
56289	Sprague Electric Co., North Adams, Mass.	85628	King Engineering Co., Baltimore, Md.
70903	Belden Mfg. Co., Chicago, Ill.	85682	Ringel Bros., Newark, N.J.
71400	Bussman Fuse, Division of McGraw-Edison Co., St. Louis, Mo.	86684	RCA Electron Tube, Division of Radio Corp. of America, Harrison, N.J.
71785	Cinch Mfg. Corp., Chicago, Ill.	88044	Aeronautical Standards Group, Departments of Navy and Air Force, Washington, D.C.
72765	Drake Mfg. Co., Chicago, Ill.	91506	Augat Bros., Inc., Attleboro, Mass.
72982	Erie Resistor Corp., Erie, Pa.	91637	Dale Products, Inc., Columbus, Nebr.
73734	Federal Screw Products Co., Chicago, Ill.	91662	Elco Corp., Philadelphia, Pa.
75915	Littlefuse, Inc., Des Plaines, Ill.	93519	General Electric Co., Lamp Works, Oakland, Calif.
78189	Shakeproof, Division of Illinois Tool Works, Elgin, Ill.	96906	Military Standards
81482	Cooperative Industries, Inc., Chester, N.J.	99849	St. Louis Blow Pipe and Heater Co., Inc., St. Louis, Mo.
82577	Hughes Aircraft Co., Culver City, Calif.		

HOW TO USE THIS ILLUSTRATED PARTS BREAKDOWN

1 FIND PAGE NO. IN TABLE OF CONTENTS
2 TURN TO PAGE
3 FIND PART AND ITS INDEX NO.
4 LOCATE INDEX NO. ON PARTS LIST

5 FIND PART NO. IN NUMERICAL LIST
6 TURN TO FIGURE AND INDEX NO.
7 LOCATE PART ON ILLUSTRATION

8 LOCATE REFERENCE DESIGNATION
9 TURN TO FIGURE AND INDEX NO.
10 LOCATE PART ON ILLUSTRATION

Section VIII
 Numerical Index
 T.O. 33A1-12-349-1

Section VII
 Group Assembly Parts List
 T.O. 33A1-12-349-1

Section IX
 Reference Designation Index
 T.O. 33A1-12-349-1

Figure 7-6
 Printed Circuit Board Assembly, Part No. 4000-55C

FIG. & INDEX NO.	R-P STOCK NO.	MFR. OR MIL. PART NO.	DESCRIPTION
7-6-	4000-55C	4000-55C	PRINTED CIRCUIT BOARD ASS (2848) (See figure 7-2, index 58)
1	3160-0005	160P47396	highly resist. film
2	0687-4701	RC20G470K	RESISTOR, FIXED, PAPER
3	2100-0151	2100-0151	DIODE, RECTIFIER, 1N4001
4	0730-0029	DC-1-10K	RESISTOR, VARIABLE, 10K
5	0687-1001	RC20G100K	RESISTOR, FIXED, COIL
6	0687-3901	RC20G390K	RESISTOR, FIXED, COIL
7	0140-0084	CM35E472J	CONDENSATOR, ELECTROLYTIC, 4700 µF, 50V
8	0120-0003	503-000-C900-10R	RESISTOR, FIXED, COIL
9	0730-0143	DC-1-10 31M	RESISTOR, VARIABLE, 31M
10	4000-55C-1	4000-55C-1	PRINTED CIRCUIT BOARD ASS (2848) (See figure 7-2, index 58)

HOW TO FIND THE PART NUMBER IF THE MAJOR ASSEMBLY IN WHICH THE PART IS USED IS KNOWN.

- Turn to the Table of Contents and find the page number for the major assembly in which the part is used.
- Turn to the page determined in step (1).
- Locate the part and its index number on the illustration.
- Find the index number on the Group Assembly Parts List page to determine the complete description.

HOW TO FIND THE ILLUSTRATION FOR A PART IF THE PART NUMBER IS KNOWN.

- Refer to the Part No. Numerical Index in Section VIII and find the part number.
- Turn to Section VII and find the first figure and index number that was indicated in the Part No.

Numerical Index for that part. If this figure shows the part in a major assembly other than the one desired, refer to the other figure numbers listed in the Part No. Numerical Index.

- On the face of the illustration, find the index number determined in step (6).

HOW TO FIND THE PART AND ILLUSTRATION NUMBER FOR AN ELECTRONIC OR ELECTRICAL PART IF THE REFERENCE DESIGNATION IS KNOWN.

- Refer to Section IX, Reference Designation Index, and find the reference designation. The part number and the figure and index number will be shown in the right-hand columns opposite the reference designation.
- Turn to Section VII and find the figure and index number shown for the part in the "FIG. AND INDEX NO." column of the Reference Designation Index.
- On the face of the illustration, find the index number determined in step (9).

SECTION VII

GROUP ASSEMBLY PARTS LIST

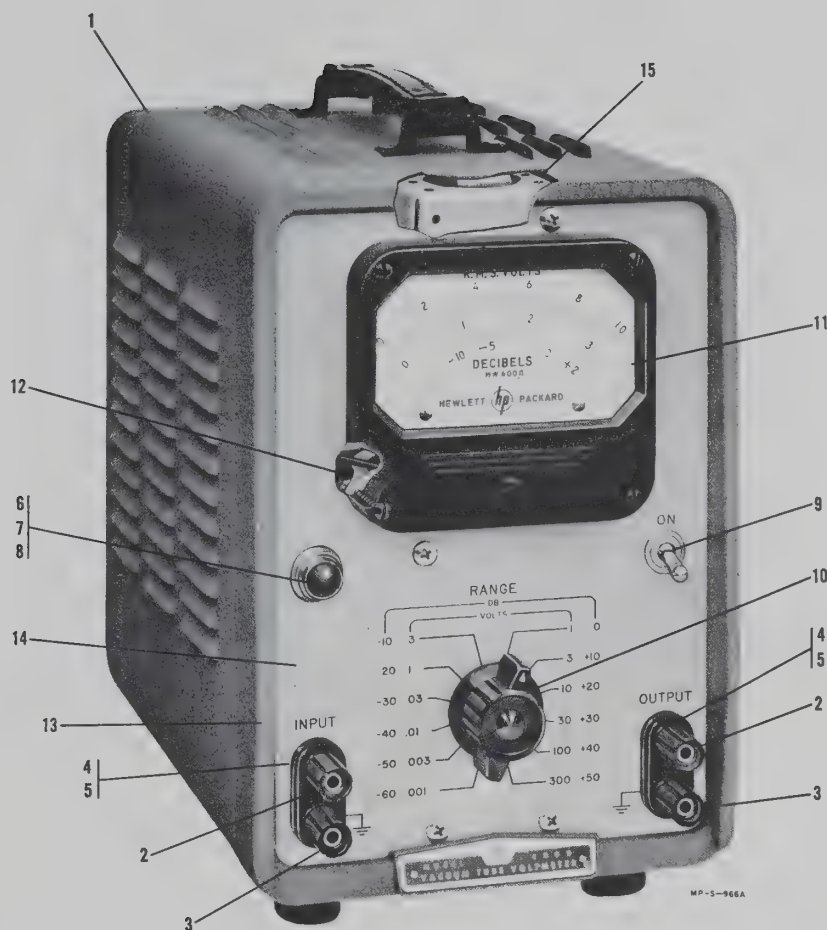


Figure 7-1. 400D/H/L Vacuum Tube Voltmeter

FIG. & INDEX NO.	H-P STOCK NO.	MRF. OR MIL PART NO.	DESCRIPTION							UNITS PER ASSY
			1	2	3	4	5	6	7	
7-1- -1	(D)	400D	VACUUM TUBE VOLTMETER (28480) . . .							1
	(H)	400H	VACUUM TUBE VOLTMETER (28480) . . .							1
	(L)	400L	VACUUM TUBE VOLTMETER (28480) . . .							1
	(H02)	H02-400D	VACUUM TUBE VOLTMETER (28480) . . .							1
		400D-44	CABINET ASSEMBLY (28480)							1
			(ATTACHING PARTS)-							
			SCREW, MACHINE							2
			---*---							

FIG. & INDEX NO.	H-P STOCK NO.	MFR. OR MIL PART NO.	DESCRIPTION							UNITS PER ASSY
			1	2	3	4	5	6	7	
7-1-		NO NUMBER	.						PANEL ASSEMBLY, FRONT	1
									(ATTACHING PARTS)	
	2520-0003	AN526-832-8	.						SCREW, MACHINE	5
	2580-0003	510-081810-01	.						NUT, ASSEMBLED WASHER (78189) . .	1
									---*---	
-2	5060-0634	5060-0634	.	.					POST, BINDING, Red (28480)	2
-3	5060-0635	5060-0635	.	.					POST, BINDING, Black (28480) . . .	2
-4	0340-0089	0340-0089	.	.					INSULATOR, STANDOFF (28480) . .	2
-5	0340-0090	0340-0090	.	.					INSULATOR, STANDOFF (28480) . .	2
-6	1450-0020	14L-15	.	.					LENS, INDICATOR LIGHT (72765) .	1
-7	2140-0012	12	.	.					LAMP, INCANDESCENT, 6-8 VOLT, 2 pin base (93519)	1
-8	1450-0022	2020-AE	.	.					LAMPHOLDER, 2 pin base (72765) .	1
-9	3101-0001	80994-H	.	.					SWITCH, TOGGLE, SPST (04009) . .	1
-10	0370-0035	0370-0035	.	.					KNOB (28480)	1
-11 (D, H02)	1120-0005	1120-0005	.	.					MULTIMETER, REPLACEMENT . .	1
									(28480)	
(H)	1120-0301	1120-0301	.	.					MULTIMETER, REPLACEMENT . .	1
									(28480)	
(L)	1120-0098	1120-0098	.	.					MULTIMETER, REPLACEMENT . .	1
									(28480)	
-12	1400-0015	1550	.	.					CLAMP, LOOP (73734)	1
-13	5020-0137	5020-0137	.	.					BEZEL, INSTRUMENT MOUNTING (28480)	1
									(ATTACHING PARTS)	
	2360-0003	AN515-6-4	.	.					SCREW, MACHINE	6
									---*---	
-14 (D, H02)	400D-2	400D-2	.	.					PANEL, FRONT (28480)	1
(H, L)	400H-2A	400H-2A	.	.					PANEL, FRONT (28480)	1
-15		NO NUMBER	.						MAIN CHASSIS ASSEMBLY	1
									(See figure 7-2) (28480)	

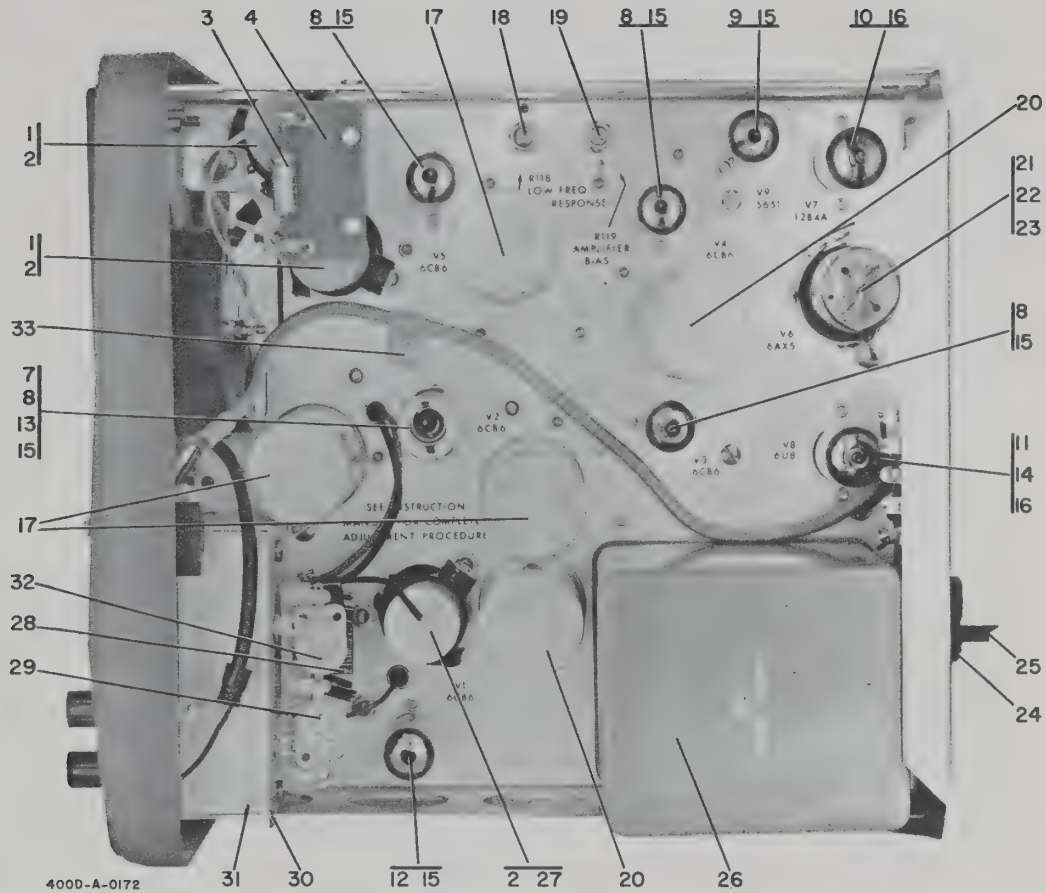


Figure 7-2. Main Chassis Assembly (Sheet 1 of 2)

FIG. & INDEX NO.	H-P STOCK NO.	MFR. OR MIL PART NO.	DESCRIPTION							UNITS PER ASSY
			1	2	3	4	5	6	7	
7-2-		NO NUMBER	MAIN CHASSIS ASSEMBLY (28480) (See figure 7-1, index 15 for next higher assembly)							REF
-1	0170-0002	663UW20504	. CAPACITOR, FIXED, PAPER DIELECTRIC, 2.0 μ f \pm 20%, 400 wvdc (84411)							2
-2	1390-0020	INSULOID N3	. CLAMP, LOOP (85628)							3
	2420-0001	510-061810-01	(ATTACHING PARTS) . NUT, ASSEMBLED WASHER (78189) . . . -----							3
-3 (D, H02)	0180-0063	30D120A1	. CAPACITOR, FIXED, ELECTROLYTIC, . 500 μ f +100%, -10%, 3 wvdc (56289)							1
(H, L)	0180-0033	30D133A1	. CAPACITOR, FIXED, ELECTROLYTIC, . 50 μ f, 6 wvdc (56289)							1
-4	400D-75H	400D-75H	. BRACKET, CAPACITOR (28480)							1
	2390-0009	COML	(ATTACHING PARTS) . SCREW, ASSEMBLED WASHER, 6-32 by 3/8 in. lg, s.s. -----							1

Section VII
Group Assembly Parts List

T.O. 33A1-12-349-1

FIG. & INDEX NO.	H-P STOCK NO.	MFR. OR MIL PART NO.	DESCRIPTION							UNITS PER ASSY
			1	2	3	4	5	6	7	
7-2-										
-7	1220-0010	126	.						SHIELD,ELECTRON TUBE (91662) . . .	1
-8	1923-0028	6CB6	.						ELECTRON TUBE (24446)	5
-9	1940-0001	5651	.						ELECTRON TUBE (86684)	1
-10	1921-0010	12B4	.						ELECTRON TUBE (24446)	1
-11	1933-0004	6U8	.						ELECTRON TUBE (24446)	1
-12	5080-0621	6CB6	.						ELECTRON TUBE (24446)	1
-13	1220-0005	429-.125	.						BASE,Tube shield (91662)	1
-15	1200-0009	316PH-3702	.						SOCKET,ELECTRON TUBE (91662) . . .	6
-16	1200-0008	44F-16388	.						SOCKET,ELECTRON TUBE (71785) . . .	2
-17	0180-0025	D32452	.						CAPACITOR,FIXED,ELECTROLYTIC, .	3
									4 section,20 μ f per section,450 wvdc (56289)	
-18	2100-0080	2100-0080	.						RESISTOR,VARIABLE,1M \pm 30%,0.2w . .	1
									(28480)	
-19	2100-0136	2100-0136	.						RESISTOR,VARIABLE,6K \pm 20%,0.3w . .	1
									(28480)	
-20	0180-0028	D27390	.						CAPACITOR,FIXED,ELECTROLYTIC, .	2
									2 section,1500 μ f per section,15 wvdc (56289)	
-21	1930-0014	6AX5-GT	.						ELECTRON TUBE (86684)	1
-22	1400-0033	120D5-63AHS	.						RETAINER,ELECTRON TUBE (91506) .	1
-23	1200-0020	51A12272	.						SOCKET,ELECTRON TUBE (71785) . . .	1
-24	0400-0013	5P-1	.						GROMMET,PLASTIC (28520)	1
-25 (D,H,L)	8120-0050	CS-9941/PH151/ 7.5FT	.						CABLE ASSEMBLY,POWER,	1
									ELECTRICAL (70903)	
(H02)	H02-400D- PWR-CORD	H02-400D-PWR- CORD	.						CABLE ASSEMBLY,POWER,	1
									ELECTRICAL (28480)	
(H02)		CS-9941/PH151/ 7.5FTW/O PLUG	.						CABLE,POWER,ELECTRICAL (70903)	1
(H02)	1251-0037	MS24663	.						CONNECTOR,PLUG,ELECTRICAL (96906)	1
-26	9100-0050	9100-0050	.						TRANSFORMER,POWER,STEP-DOWN AND STEP-UP (28480)	1
									(ATTACHING PARTS)	
	2900-0001	510-101810-51	.						NUT,ASSEMBLED WASHER (78189) . . .	4
									---*---	
-27	0170-0057	S70375	.						CAPACITOR,FIXED,PAPER	1
									DIELECTRIC,5 μ f \pm 10%,100 wvdc (56289)	
-28	0130-0006	503-000-B2P0-28R	.						CAPACITOR,VARIABLE,CERAMIC . .	1
									DIELECTRIC,5-20 pf,500 wvdc (72982) .	
-29	0130-0001	503-000-D2P0-33R	.						CAPACITOR,VARIABLE,CERAMIC . .	1
									DIELECTRIC,7-45 pf,500 wvdc (72982) .	
-30	400D-6J	400D-6J	.						SHIELD,ROTARY SWITCH (28480) . . .	1
									(ATTACHING PARTS)	
	2550-0007	COML	.						SCREW,ASSEMBLED WASHER,8-32 by 3/8 in. lg,s.s.	2
									---*---	
-31	400D-6K	400D-6K	.						BRACKET,ANGLE (28480)	1
									(ATTACHING PARTS)	
	2390-0009	COML	.						SCREW,ASSEMBLED WASHER,6-32 by 3/8 in. lg,s.s.	2
									---*---	
-32	400D-19A	400D-19A	.						RANGE SWITCH ASSEMBLY (28480) . .	1
									(See figure 7-3)	

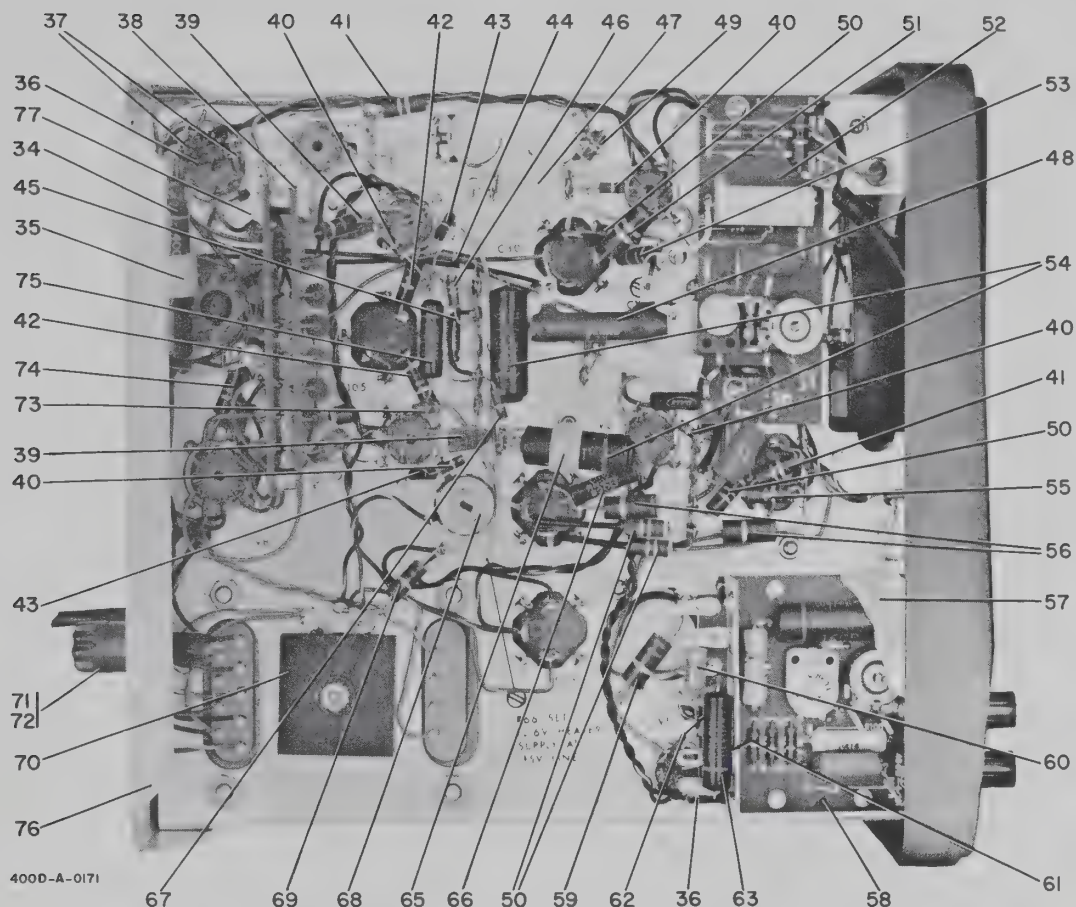


Figure 7-2. Main Chassis Assembly (Sheet 2 of 2)

FIG. & INDEX NO.	H-P STOCK NO.	MFR. OR MIL PART NO.	DESCRIPTION							UNITS PER ASSY
			1	2	3	4	5	6	7	
7-2-33	1400-0074	INSULOID C3	.	CLAMP, LOOP (85682)	.	.	.	.	.	1
	2390-0009	COML	.	(ATTACHING PARTS)						
	3050-0100	AN960-6	.	SCREW, ASSEMBLED WASHER, 6-32 by						1
	2420-0001	510-061810-01	.	3/8 in. lg, s.s.						
			.	WASHER, FLAT (88044)	.	.	.	.	.	1
			.	NUT, ASSEMBLED WASHER (78189)	.	.	.	.	.	1
			.	----						
-34	0160-0024	PKM 4P5	.	CAPACITOR, FIXED, PAPER	.	.	.	.	.	1
			.	DIELECTRIC, 0.5 μ f \pm 10%, 400 wvdc (14655)	.	.	.	.	.
-35	1400-0016	781	.	CLAMP, LOOP (83330)	.	.	.	.	.	1
	2390-0001	COML	.	(ATTACHING PARTS)						
	2420-0001	510-061810-01	.	SCREW, ASSEMBLED WASHER, 6-32 by						1
			.	1/2 in. lg, s.s. (78189)	.	.	.	.	.
			.	NUT, ASSEMBLED WASHER (78189)	.	.	.	.	.	1
			.	----						
-36	0687-4711	RC20GF471K	.	RESISTOR, FIXED, COMPOSITION,	.	.	.	.	.	2
			.	470 ohm \pm 10%, 1/2w (MIL-R-11)	.	.	.	.	.
-37	0687-4741	RC20GF474K	.	RESISTOR, FIXED, COMPOSITION,	.	.	.	.	.	2
			.	470K \pm 10%, 1/2w (MIL-R-11)	.	.	.	.	.

Section VII
Group Assembly Parts List

T.O. 33A1-12-349-1

FIG. & INDEX NO.	H-P STOCK NO.	MFR. OR MIL PART NO.	DESCRIPTION							UNITS PER ASSY
			1	2	3	4	5	6	7	
7-2-38	400D-75G	400D-75G	.	PRINTED CIRCUIT BOARD ASSEMBLY (28480) (See figure 7-4)						1
				(ATTACHING PARTS)						
	2390-0009	COML	.	SCREW, ASSEMBLED WASHER, 6-32 by 3/8 in. lg, s.s. ---*---						2
-39	0150-0012	29C214A3-H-1038	.	CAPACITOR, FIXED, CERAMIC DIELECTRIC, 0.01 μ f \pm 20%, 1000 wvdc (56289)						3
-40	0687-4701	RC20GF470K	.	RESISTOR, FIXED, COMPOSITION, . . . 47 ohm \pm 10%, 1/2w (MIL-R-11)						4
-41	0690-2241	RC32GF224K	.	RESISTOR, FIXED, COMPOSITION, . . . 220K \pm 10%, 1w (MIL-R-11)						2
-42	0699-0005	RC32GF2R7K	.	RESISTOR, FIXED, COMPOSITION, . . . 2.7 ohm \pm 10%, 1w (MIL-R-11)						2
-43	0687-5611	RC20GF561K	.	RESISTOR, FIXED, COMPOSITION, . . . 560 ohm \pm 10%, 1/2w (MIL-R-11)						2
-44	0687-2751	RC20GF275K	.	RESISTOR, FIXED, COMPOSITION, . . . 2.7M \pm 10%, 1/2w (MIL-R-11)						1
-45	0180-0033	30D133A1	.	CAPACITOR, FIXED, ELECTROLYTIC, 50 μ f, 6 wvdc (56289)						1
-46	0687-1041	RC20GF104K	.	RESISTOR, FIXED, COMPOSITION, . . . 100K \pm 10%, 1/2w (MIL-R-11)						1
-47	0170-0063	148P22394	.	CAPACITOR, FIXED, PLASTIC . . . DIELECTRIC, 0.020 μ f \pm 10%, 400 wvdc (56289)						1
-48	0816-0017	C-10-6.3K	.	RESISTOR, FIXED, WIRE WOUND, . . 6.3K \pm 10%, 10w (35434)						1
-49	0687-6841	RC20GF684K	.	RESISTOR, FIXED, COMPOSITION, . . 680K \pm 10%, 1/2w (MIL-R-11)						1
-50	0690-4731	RC32GF473K	.	RESISTOR, FIXED, COMPOSITION, . . 47K \pm 10%, 1w (MIL-R-11)						4
-51	0693-1031	RC42GF103K	.	RESISTOR, FIXED, COMPOSITION, . . 10K \pm 10%, 2w (MIL-R-11)						1
-52	400D-75F	400D-75F	.	PRINTED CIRCUIT BOARD ASSEMBLY (28480) (See figure 7-5)						1
				(ATTACHING PARTS)						
	2360-0012	AN526-632-14	.	SCREW, MACHINE (88044)						2
	2190-0006	AN935-6	.	WASHER, LOCK (88044)						2
	0380-0008	2102	.	SPACER, SLEEVE (83330)						2
	2420-0001	510-061810-01	.	NUT, ASSEMBLED WASHER (78189) . . ---*---						2
-53	0690-3321	RC32GF332K	.	RESISTOR, FIXED, COMPOSITION, . . 3.3K \pm 10%, 1w (MIL-R-11)						1
-54	0160-0013	160P10494	.	CAPACITOR, FIXED, PAPER DIELECTRIC, 0.1 μ f \pm 10%, 400 wvdc (56289)						2
-55	0689-1145	RC32GF114J	.	RESISTOR, FIXED, COMPOSITION, . . 110K \pm 5%, 1w (MIL-R-11)						1
-56	0693-8221	RC42GF822K	.	RESISTOR, FIXED, COMPOSITION, . . 8.2K \pm 10%, 2w (MIL-R-11)						2
-57	400D-6H	400D-6H	.	SHIELD, Input printed circuit board . . assembly (28480)						1
				(ATTACHING PARTS)						
	2420-0001	510-061810-01	.	NUT, ASSEMBLED WASHER (78189) . . ---*---						2

FIG. & INDEX NO.	H-P STOCK NO.	MFR. OR MIL PART NO.	DESCRIPTION							UNITS PER ASSY
			1	2	3	4	5	6	7	
7-2-58	400D-65C	400D-65C	.	PRINTED CIRCUIT BOARD ASSEMBLY (28480) (See figure 7-6)						1
				(ATTACHING PARTS)						
	2390-0009	COML	.	SCREW, ASSEMBLED WASHER, 6-32 by 3/8 in. lg, s.s. ---*---						2
-59	0693-6821	RC42GF682K	.	RESISTOR, FIXED, COMPOSITION, . . . 6.8K $\pm 10\%$, 2w (MIL-R-11)						1
-60	0170-0040	148P47392	.	CAPACITOR, FIXED, PLASTIC DIELECTRIC, 0.047 μ f $\pm 10\%$, 200 wvdc (56289)						1
-61	0687-2251	RC20GF225K	.	RESISTOR, FIXED, COMPOSITION, . . . 2.2M $\pm 10\%$, 1/2w (MIL-R-11)						1
-62	0687-8251	RC20GF825K	.	RESISTOR, FIXED, COMPOSITION, . . . 8.2M $\pm 10\%$, 1/2w (MIL-R-11)						1
-63	0160-0002	160P10396	.	CAPACITOR, FIXED, PAPER DIELECTRIC, 0.01 μ f $\pm 10\%$, 600 wvdc (56289)						1
-64	400D-6F	400D-6F	.	MOUNTING PLATE, Shield (56289) . . .						1
				(ATTACHING PARTS)						
	2420-0001	510-061810-01	.	NUT, ASSEMBLED WASHER (78189) . . ---*---						2
-65	1400-0025	777	.	CLAMP, LOOP (83380)						1
				(ATTACHING PARTS)						
	2420-0001	510-061810-01	.	NUT, ASSEMBLED WASHER (78189) . . ---*---						2
-66	0761-0001	N25-8.2K	.	RESISTOR, FIXED, FILM, 8.2K $\pm 5\%$, 1w . (14674)						1
-67	0687-1251	RC20GF125K	.	RESISTOR, FIXED, COMPOSITION, . . . 1.2M $\pm 10\%$, 1/2w (MIL-R-11)						1
-68	2100-0077	2100-0077	.	RESISTOR, VARIABLE, 4 ohm $\pm 20\%$, 1w . (28480)						1
-69	0690-1001	RC32GF100K	.	RESISTOR, FIXED, COMPOSITION, . . . 10 ohm $\pm 10\%$, 1w (MIL-R-11)						1
-70	1882-0005	61-6911	.	RECTIFIER, METALLIC (81482) . . .						1
				(ATTACHING PARTS)						
	2370-0009	MS35239-42	.	SCREW, MACHINE (96906)						1
	2420-0001	510-061810-01	.	NUT, ASSEMBLED WASHER (78189) . . ---*---						1
-71	2110-0007	MDL-1	.	FUSE, CARTRIDGE, 1 amp, 250v, slow blow for 115v (71400)						1
-72	1400-0084	342014	.	FUSEHOLDER (75915)						1
-73	0687-3351	RC20GF335K	.	RESISTOR, FIXED, COMPOSITION, 3.3M $\pm 10\%$, 1/2w (MIL-R-11)						1
-74	0690-1831	RC32GF183K	.	RESISTOR, FIXED, COMPOSITION, . . . 18K $\pm 10\%$, 1w (MIL-R-11)						1
-75	0160-0044	160P27296	.	CAPACITOR, FIXED, PAPER DIELECTRIC, 0.0027 μ f $\pm 10\%$, 600 wvdc (56289)						1
-76	400D-1A	400D-1A	.	PANEL, Rear (28480)						1
-77	400D-1B	400D-1B	.	CHASSIS, ELECTRICAL EQUIPMENT . (28480)						1

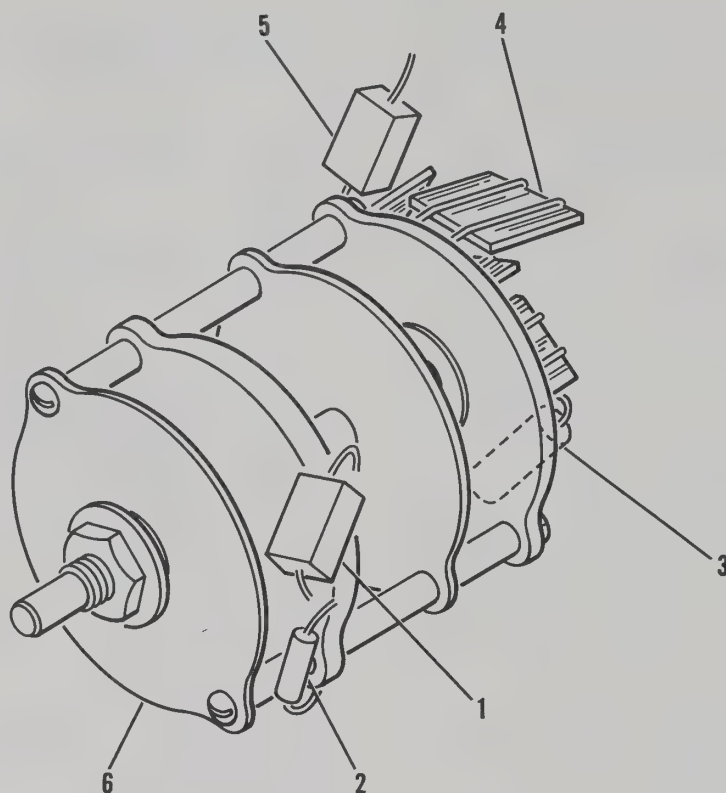


Figure 7-3. Range Switch Assembly

FIG. & INDEX NO.	H-P STOCK NO.	MFR. OR MIL PART NO.	DESCRIPTION							UNITS PER ASSY
			1	2	3	4	5	6	7	
7-3-	400D-19A	400D-19A	RANGE SWITCH ASSEMBLY (28480) (See figure 7-2, index 32 for next higher assembly)							REF
-1	0140-0039	CM15E470J	. CAPACITOR, FIXED, MICA DIELECTRIC, 47 pf $\pm 10\%$, 500 wvdc (MIL-C-5)							1
-2	0687-1531	RC20GF153K	. RESISTOR, FIXED, COMPOSITION, . . . 15K $\pm 10\%$, 1/2w (MIL-R-11)							1
-3	0150-0009	315-000-C0G0-100D	. CAPACITOR, FIXED, CERAMIC DIELECTRIC, 10 pf ± 0.5 pf, 500 wvdc (72982)							1
-4	400D-26G	400D-26G	. RESISTOR ASSEMBLY, Matched set of 6 wire wound resistors, replaceable only as a set (28480)							1
-5	0140-0014	CM15E560J	. CAPACITOR, FIXED, MICA DIELECTRIC, 56 pf $\pm 10\%$, 500 wvdc (MIL-C-5)							1
-6	3100-0251	3100-0251	. SWITCH, ROTARY, Not separately . . . replaceable (28480)							1

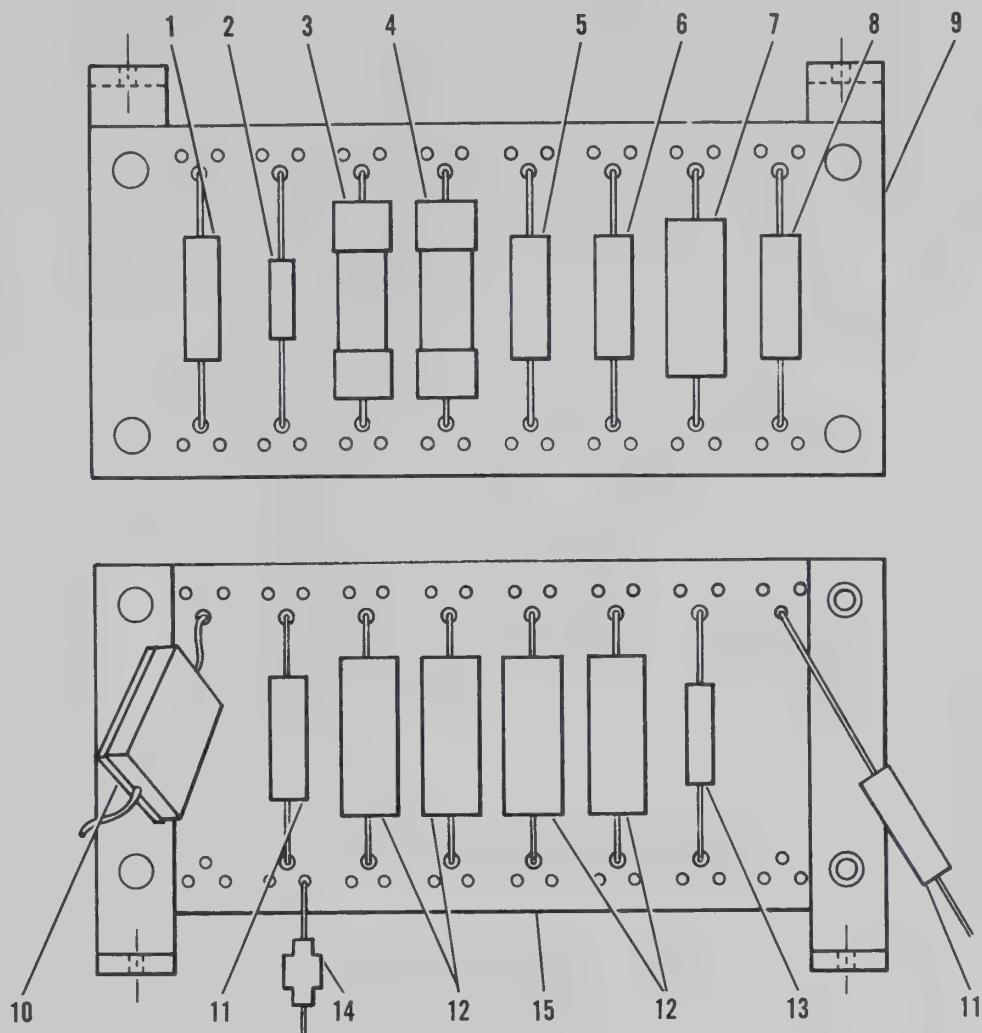


Figure 7-4. Printed Circuit Board Assembly, Part No. 400D-75G

FIG. & INDEX NO.	H-P STOCK NO.	MFR. OR MIL PART NO.	DESCRIPTION							UNITS PER ASSY
			1	2	3	4	5	6	7	
7-4-	400D-75G	400D-75G	PRINTED CIRCUIT BOARD ASSEMBLY (28480) (See figure 7-2, index 38 for next higher assembly)							REF
-1	0690-6831	RC32GF683K	. RESISTOR, FIXED, COMPOSITION, . . . 68K $\pm 10\%$, 1w (MIL-R-11)							1
-2	0687-1041	RC20GF104K	. RESISTOR, FIXED, COMPOSITION, . . . 100K $\pm 10\%$, 1/2w (MIL-R-11)							1
-3	0730-0065	DC-1-90.5K	. RESISTOR, FIXED, FILM, 90.5K $\pm 1\%$, 1w . (19701)							1
-4	0730-0076	DC-1-166K	. RESISTOR, FIXED, FILM, 166K $\pm 1\%$, 1w . (19701)							1
-5	0690-1241	RC32GF124K	. RESISTOR, FIXED, COMPOSITION, . . . 120K $\pm 10\%$, 1w (MIL-R-11)							1
-6	0690-5631	RC32GF563K	. RESISTOR, FIXED, COMPOSITION, . . . 56K $\pm 10\%$, 1w (MIL-R-11)							1
-7	0693-1841	RC42GF184K	. RESISTOR, FIXED, COMPOSITION, . . . 180K $\pm 10\%$, 2w (MIL-R-11)							1

FIG. & INDEX NO.	H-P STOCK NO.	MFR. OR MIL PART NO.	DESCRIPTION							UNITS PER ASSY
			1	2	3	4	5	6	7	
7-4-8	0690-3341	RC32GF334K	.	RESISTOR, FIXED, COMPOSITION, . . .						1
-9	400D-75G-2	400D-75G-2	.	PRINTED CIRCUIT BOARD (28480) . . .						1
-10	0140-0007	CM20B681K	.	CAPACITOR, FIXED, MICA DIELECTRIC, . . .						1
				680 pf $\pm 10\%$, 500 wvdc (MIL-C-5)						
-11	0689-2425	RC32GF242J	.	RESISTOR, FIXED, COMPOSITION, . . .						2
				2.4K $\pm 5\%$, 1w (MIL-R-11)						
-12	0693-2731	RC42GF273K	.	RESISTOR, FIXED, COMPOSITION, . . .						4
				27K $\pm 10\%$, 2w (MIL-R-11)						
-13	0140-0025	CM15E680K	.	CAPACITOR, FIXED, MICA DIELECTRIC, . . .						1
				68 pf $\pm 10\%$, 500 wvdc (MIL-C-5)						
-14	9140-0040	42 μ H-10%- PHENOLIC FORM	.	COIL, RF, 42 μ h $\pm 10\%$ (99849)						1
-15	400D-75G-1	400D-75G-1	.	PRINTED CIRCUIT BOARD (28480) . . .						1

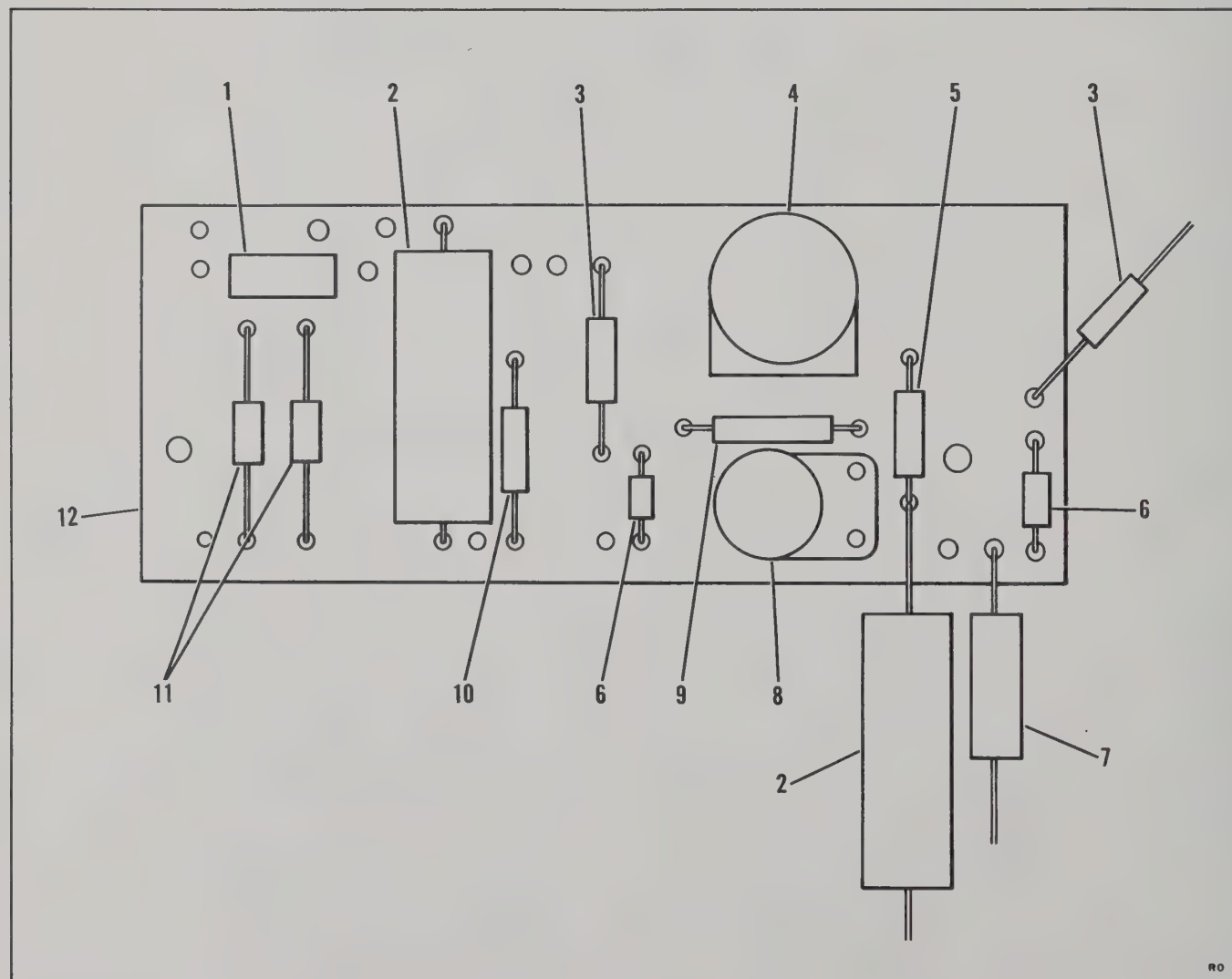


Figure 7-5. Printed Circuit Board Assembly, Part No. 400D-75F

FIG. & INDEX NO.	H-P STOCK NO.	MFR. OR MIL PART NO.	DESCRIPTION							UNITS PER ASSY
			1	2	3	4	5	6	7	
7-5-	400D-75F	400D-75F	PRINTED CIRCUIT BOARD ASSEMBLY . . (28480) (See figure 7-2, index 52 for next higher assembly)							REF
-1	0689-5105	RC32GF510J	.	RESISTOR, FIXED, COMPOSITION, . .						1
-2	0170-0064	148P47491	.	51 ohm $\pm 5\%$, 1w (MIL-R-11)						2
-3	400D-26F	400D-26F	.	CAPACITOR, FIXED, PAPER						2
-4	2100-0108	2100-0108	.	DIELECTRIC, 0.47 μ f $\pm 10\%$, 100 wvdc (56289)						2
-5	400D-26C	400D-26C	.	RESISTOR, FIXED, WIRE WOUND, . . .						1
-6	400D-60A	400D-60A	.	10 ohm $\pm 0.5\%$, 1/2w (28480)						1
-7	0813-0009	CS-2-125	.	RESISTOR, VARIABLE, 100 ohm $\pm 30\%$, 1/3w (28480)						1
-8	0130-0002	557-000-U2P0-34R	.	RESISTOR, FIXED, WIRE WOUND, . . .						1
-9	0727-0018	DC-1/2C-40	.	205 ohm $\pm 0.5\%$ (28480)						2
-10	0686-5115	RC20GF511J	.	COIL, RADIO FREQUENCY, 0.05 μ h (28480)						1
-11	1901-0027	HD-5004	.	RESISTOR, FIXED, COMPOSITION, . . .						1
-12	400D-75F-1	400D-75F-1	.	125 ohm $\pm 10\%$, 2w (91637)						2
			.	CAPACITOR, VARIABLE, CERAMIC . .						1
			.	DIELECTRIC, 8-50 pf, 350 wvdc (72982)						1
			.	RESISTOR, FIXED, FILM,						1
			.	40 ohm $\pm 1\%$, 1/2w (19701)						1
			.	RESISTOR, FIXED, COMPOSITION, . . .						2
			.	510 ohm $\pm 5\%$, 1/2w (MIL-R-11)						1
			.	SEMICONDUCTOR DEVICE, DIODE (82577)						2
			.	PRINTED CIRCUIT BOARD (28480) . .						1

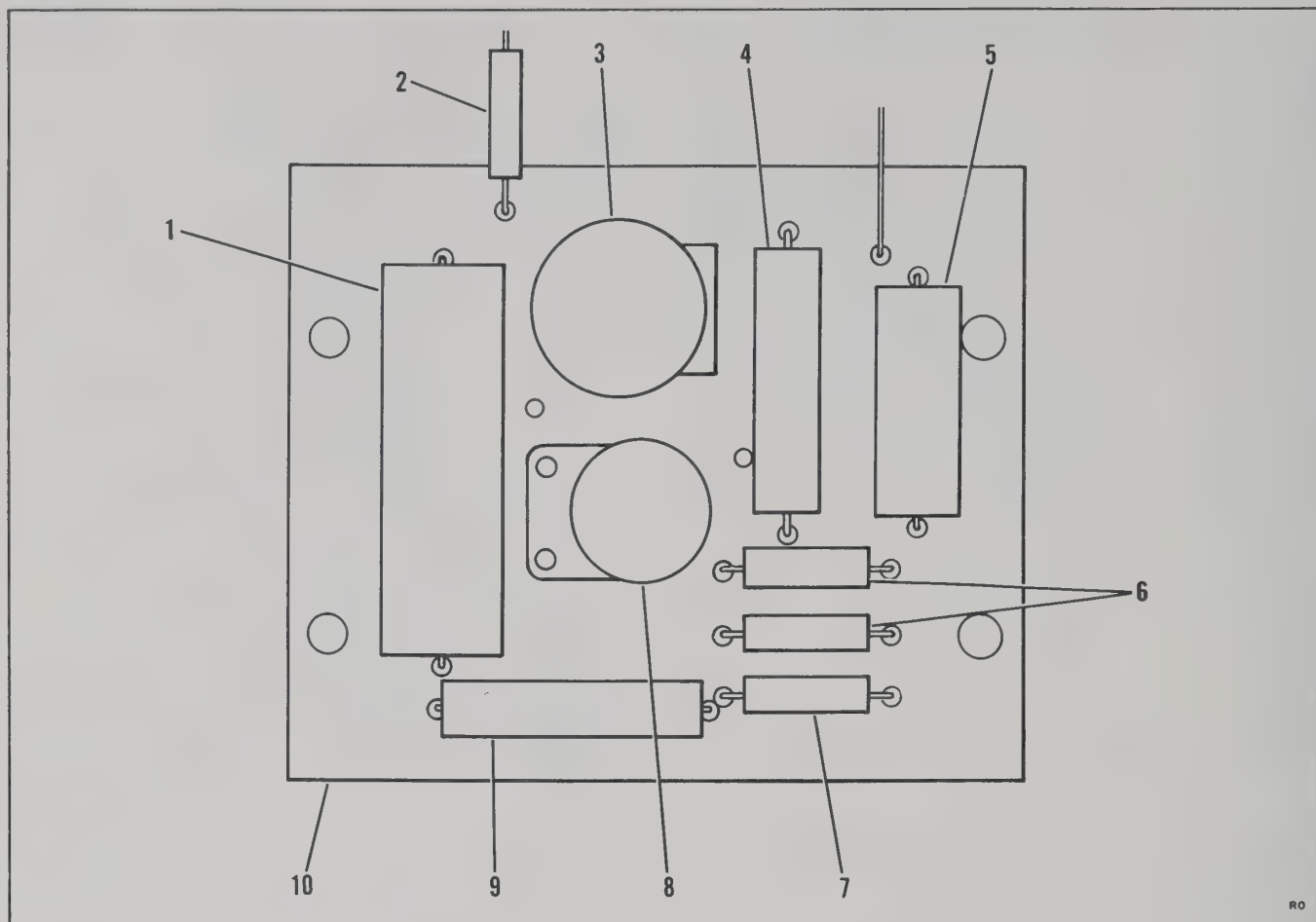


Figure 7-6. Printed Circuit Board Assembly, Part No. 400D-65C

FIG. & INDEX NO.	H-P STOCK NO.	MFR. OR MIL PART NO.	DESCRIPTION							UNITS PER ASSY
			1	2	3	4	5	6	7	
7-6-	400D-65C	400D-65C	PRINTED CIRCUIT BOARD ASSEMBLY . . (28480) (See figure 7-2, index 58 for next higher assembly)							REF
-1	0160-0005	160P47396	. CAPACITOR, FIXED, PAPER							1
			. DIELECTRIC, 0.047 μ f \pm 10%, 600 wvdc (56289)							1
-2	0687-4701	RC20GF470K	. RESISTOR, FIXED, COMPOSITION, . . .							1
			47 ohm \pm 10%, 1/2w (MIL-R-11)							
-3	2100-0151	2100-0151	. RESISTOR, VARIABLE, 500 ohm \pm 20%, 1/5w (28480)							1
-4	0730-0029	DC-1-10K	. RESISTOR, FIXED, FILM, 10K \pm 1%, 1w . (19701)							1
-5	0140-0084	CM35E472J	. CAPACITOR, FIXED, MICA DIELECTRIC, 4700 pf \pm 5%, 500 wvdc (MIL-C-5)							1
-6	0687-1001	RC20GF100K	. RESISTOR, FIXED, COMPOSITION, . .							2
			10 ohm \pm 10%, 1/2w (MIL-R-11)							
-7	0687-5601	RC20GF560K	. RESISTOR, FIXED, COMPOSITION, . .							1
			56 ohm \pm 10%, 1/2w, value selected at factory, optimum value show (MIL-R-11)							
-8	0130-0003	503-000-C0P0-10R	. CAPACITOR, VARIABLE, CERAMIC DIELECTRIC, 1.5-7 pf, 500 wvdc (72982)							1
-9	0730-0143	DC-1-10.31M	. RESISTOR, FIXED, FILM, 10.31M \pm 1%, 1w (19701)							1
-10	400D-65C-1	400D-65C-1	. PRINTED CIRCUIT BOARD (28480) . .							1

SECTION VIII

NUMERICAL INDEXES

PART NO. NUMERICAL INDEX

MFR. OR MIL. PART NO.	STOCK NO.		FIG. AND INDEX NO.	QTY PER ART.	SOURCE CODE
	CLASS CODE	SERIAL OR PART NO.			
1120-0098	6625		7-1-11	1	
1120-0301	6625		7-1-11	1	
12	6240		7-1-7	1	
12B4A	5960		7-2-10	1	
120D5-63AHS	5960		7-2-22	1	
126	5960		7-2-7	1	
14L-15	6210		7-1-6	1	
148P22394	5910		7-2-47	1	
148P47392	5910		7-2-60	1	
148P47491	5910		7-5-2	2	
1550	5340		7-1-12	1	
160P10396	5910		7-2-63	1	
160P10494	5910		7-2-64	2	
160P27296	5910		7-2-75	1	
160P47396	5910		7-6-1	1	
2020-AE	6250		7-1-8	1	
2100-0077	5905		7-2-68	1	
2100-0080	5905		7-2-18	1	
2100-0108	5905		7-5-4	1	
2100-0136	5905		7-2-19	1	
2100-0151	5905		7-6-3	1	
2102	5340		7-2-	2	
29C214A3-H-1038	5910		7-2-39	3	
30D120A1	5910		7-2-3	1	
30D133A1	5910		7-2-3	2	
			7-2-45		
3100-0251	5930		7-3-6	1	
315-000-C0G0-100D	5910		7-3-3	1	
316PH-3702	5935		7-2-15	6	
342014	5920		7-2-72	1	
400D	6625-643-1670		7-1-	1	
400D-1A			7-2-76	1	
400D-1B	5999		7-2-77	1	
400D-19A			7-2-32	1	
400D-2			7-1-14	1	
400D-26C	5905		7-5-5	1	
400D-26F	5905		7-5-3	2	
400D-26G	5905		7-3-4	1	
400D-44			7-1-1	1	
400D-6F			7-2-64	1	
400D-6H			7-2-57	1	
400D-6J	5930		7-2-30	1	
400D-6K	5940		7-2-31	1	
400D-60A	5950		7-5-6	2	
400D-65C			7-2-58	1	
400D-65C-1	5999		7-6-10	1	
400D-75F			7-2-52	1	
400D-75F-1	5999		7-5-12	1	
400D-75G			7-2-38	1	
400D-75G-1	5999		7-4-15	1	
400D-75G-2	5999		7-4-9	1	
400D-75H			7-2-4	1	
400H	6625-557-8261		7-1-	1	
400H-2A			7-1-14	1	
400L	6625-729-8360		7-1-	1	
42μH-10%-PHENOLIC FORM	5950		7-4-14	1	
429-.125			7-2-13	1	
44F-16388	5935		7-2-16	2	
5P-1	5325		7-2-24	1	
5020-0137			7-1-13	1	
503-000-B2P0-28R	5910		7-2-28	1	
503-000-C0P0-10R	5910		7-6-8	1	
503-000-D2P0-33R	5910		7-2-29	1	
5060-0634	5940		7-1-2	2	
5060-0635	5940		7-1-3	2	
51A12272	5935		7-2-23	1	
510-061810-01	5310		7-2-	12	
510-081810-01	5310		7-1-	1	
557-000-U2P0-34R	5910		7-5-8	1	
5651	5960		7-2-9	1	
6AX5-GT	5960		7-2-21	1	
6CB6	5960		7-2-8	5	
			7-2-12		
6U8	5960		7-2-11	1	
61-6911	6130		7-2-70	1	
663UW20504	5910		7-2-1	2	
777	5340		7-2-65	1	
781	5340		7-2-35	1	
80994-H	5930		7-1-10	1	
9100-0050	5950		7-2-26	1	

MFR. OR MIL. PART NO.	STOCK NO.		FIG. AND INDEX NO.	QTY PER ART.	SOURCE CODE
	CLASS CODE	SERIAL OR PART NO.			
AN515-6-4	5305		7-1-	6	
AN526-632-14	5305		7-2-	2	
AN526-832-10	5905		7-1-	2	
AN526-832-8	5305		7-1-	5	
AN935-6	5310		7-2-	2	
AN960-6	5310		7-2-	1	
C-10-6.3K	5905		7-2-48	1	
CM15B680K	5910		7-4-13	1	
CM15E470J	5910		7-3-1	1	
CM15E560J	5910		7-3-5	1	
CM20B681K	5910		7-4-10	1	
CM35E472J	5910		7-6-5	1	
CS-2-125	5905		7-5-7	1	
CS-9941/PH151/7.5FT	6145		7-2-25	1	
CS-9941/PH151/7.5FT	6145		7-2-25	1	
W/O PLUG					
DC-1/2C-40	5905		7-5-9	1	
DC-1-10.31M	5905		7-6-9	1	
DC-1-10K	5905		7-6-4	1	
DC-1-166K	5905		7-4-4	1	
DC-1-90.5K	5905		7-4-3	1	
D27390	5910		7-2-20	2	
D32452	5910		7-2-17	3	
HD-5004	5960		7-5-11	2	
H02-400D	6625		7-1-	1	
H02-400D-PWR CORD	6145		7-2-25	1	
INSULOID C3	5340		7-2-33	1	
INSULOID N3	5340		7-2-2	3	
MAIN CHASSIS			7-1-15	1	
ASSEMBLY					
MDL-1	5920		7-2-71	1	
MS24663	5935		7-2-25	1	
MS35239-42	5305		7-2-	1	
N25-8.2K	5905		7-2-66	1	
PANEL ASSEMBLY			7-1-	1	
PKM 4P5	5910		7-2-34	1	
RC20GF100K	5905		7-6-6	2	
RC20GF104J	5905		7-2-46	1	
RC20GF104K	5905		7-4-2	1	
RC20GF125K	5905		7-2-67	1	
RC20GF153K	5905		7-3-2	1	
RC20GF225K	5905		7-2-61	1	
RC20GF275K	5905		7-2-44	1	
RC20GF335K	5905		7-2-73	1	
RC20GF470K	5905		7-2-40	5	
			7-6-2		
RC20GF471K	5905		7-2-36	2	
RC20GF474K	5905		7-2-37	2	
RC20GF511J	5905		7-5-10	1	
RC20GF560K	5905		7-6-7	1	
RC20GF561K	5905		7-2-43	2	
RC20GF684K	5905		7-2-49	1	
RC20GF825K	5905		7-2-62	1	
RC32GF100K	5905		7-2-69	1	
RC32GF114J	5905		7-2-55	1	
RC32GF124K	5905		7-4-5	1	
RC32GF183K	5905		7-2-74	1	
RC32GF2R7K	5905		7-2-42	2	
RC32GF224K	5905		7-2-41	2	
RC32GF242J	5905		7-4-11	2	
RC32GF332K	5905		7-2-53	1	
RC32GF334K	5905		7-4-8	1	
RC32GF473K	5905		7-2-50	4	
RC32GF510J	5905		7-5-1	1	
RC32GF563K	5905		7-4-6	1	
RC32GF683K	5905		7-4-1	1	
RC42GF103K	5905		7-2-51	1	
RC42GF184K	5905		7-4-7	1	
RC42GF273K	5905		7-4-12	4	
RC42GF682K	5905		7-2-59	1	
RC42GF822K	5905		7-2-56	2	
SCREW, ASSEMBLED	5305		7-2-	1	
WASHER					
SCREW, ASSEMBLED	5305		7-2-	8	
WASHER					
SCREW, ASSEMBLED	5305		7-2-	2	
WASHER					
S70375	5910		7-2-27	1	
0340-0089	5970		7-1-4	2	
0340-0090	5970		7-1-5	2	
0370-0035	5355		7-1-10	1	
1120-0005	6625		7-1-11	1	

HEWLETT-PACKARD STOCK NO. INDEX

H-P STOCK NUMBER	TOTAL QTY PER ART.	RECOM- MENDE D SPARES	H-P STOCK NUMBER	TOTAL QTY PER ART.	RECOM- MENDE D SPARES	H-P STOCK NUMBER	TOTAL QTY PER ART.	RECOM- MENDE D SPARES
H02-400D	1		0689-5105	1	1	2100-0108	1	1
H02-400D- PWR CORD	1		0690-1001	1	1	2100-0136	1	1
0130-0001	1	1	0690-1241	1	1	2100-0151	1	1
0130-0002	1	1	0690-1831	1	1	2110-0007	1	10
0130-0003	1	1	0690-2241	2	1	2140-0012	1	1
0130-0006	1	1	0690-3321	1	1	2190-0006	2	
			0690-3341	1	1	2360-0003	6	
0140-0007	1	1	0690-4731	4	1	2360-0012	2	
0140-0014	1	1	0690-5631	1	1	2370-0009	1	
0140-0025	1	1	0690-6831	1	1	2390-0001	1	
0140-0039	1	1	0693-1031	1	1	2390-0009	8	
0140-0084	1	1	0693-1841	1	1	2420-0001	14	
0150-0009	1	1	0693-2731	4	1	2520-0003	5	
0150-0012	3	1	0693-6821	1	1	2520-0006	2	
0160-0002	1	1	0693-8221	2	1	2550-0007	2	
0160-0005	1	1	0699-0005	2	1	2580-0003	1	
0160-0013	2	1	0727-0018	1	1	2900-0001	4	
0160-0024	1	1	0730-0029	1	1	3050-0100	1	
0160-0044	1	1	0730-0065	1	1	3101-0001	1	1
0170-0002	2	1	0730-0076	1	1	400D	1	
0170-0040	1	1	0730-0143	1	1	400D-1A	1	
0170-0057	1	1	0761-0001	1	1	400D-1B	1	
0170-0063	1	1	0813-0009	1	1	400D-19A	1	
0170-0064	2	1	0816-0017	1	1	400D-2	1	
0180-0025	3	1	1120-0005	1	1	400D-26C	1	1
0180-0028	2	1	1120-0091	1	1	400D-26F	2	1
0180-0033	2	1	1120-0301	1	1	400D-26G	1	1
0180-0063	1	1	1200-0008	2		400D-44	1	
			1200-0009	6		400D-6F	1	
0340-0089	2		1200-0020	1		400D-6H	1	
0340-0090	2		1220-0005	1		400D-6J	1	
0370-0035	1		1220-0010	1		400D-6K	1	
0380-0008	2		1251-0037	1		400D-60A	2	1
0400-0013	1		1390-0020	3		400D-65C	1	
0686-5115	1	1	1400-0015	1		400D-65C-1	1	
0687-1001	2	1	1400-0016	1		400D-75F	1	
0687-1041	2	2	1400-0025	1		400D-75F-1	1	
0687-1251	1	1	1400-0033	1		400D-75G	1	
0687-1531	1		1400-0074	1		400D-75G-1	1	
0687-2251	1	1	1400-0084	1		400D-75G-2	1	
0687-2751	1	1	1450-0020	1		400D-75H	1	
0687-3351	1	1	1450-0022	1		400H	1	
0687-4701	5	2	1882-0005	1	1	400H-2A	1	
0687-4711	2	1	1901-0027	2	2	400L	1	
0687-4741	2	1	1921-0010	1	1	5020-0137	1	
0687-5601	1	1	1923-0028	4	4	5060-0634	2	1
0687-5611	2	1	1930-0014	1	1	5060-0635	2	1
0687-6841	1	1	1933-0004	1	1	5080-0621	1	1
0687-8251	1	1	1940-0001	1	1	8120-0050	1	1
0689-1145	1	1	2100-0077	1	1	9100-0050	1	1
0689-2425	2	1	2100-0080	1	1	9140-0040	1	

SECTION IX

REFERENCE DESIGNATION INDEX

REFERENCE DESIGNATION	FIGURE AND INDEX NUMBER	CLASS CODE OR STOCK NUMBER	MFR. OR MIL. PART NUMBER	H-P PART NUMBER
CR1	7-5-11	5960-	HD-5004	1901-0027
CR2	7-5-11	5960-	HD-5004	1901-0027
CR3	7-2-70	6130-	61-6911	1882-0005
C1	7-2-17	5910-	D32452	0180-0025
C100	7-2-63	5910-	160P10396	0160-0002
C101	7-2-60	5910-	148P47392	0170-0040
C102	7-5-8	5910-	557-000-U2P0-34R	0130-0002
C104	7-2-27	5910-	S70375	0170-0057
C105	7-2-20	5910-	D27390	0180-0028
C106	7-3-5	5910-	CM15E560J	0140-0014
C107	7-2-45	5910-	30D133A1	0180-0033
C108	7-3-1	5910-	CM15E470J	0140-0039
C14	7-2-28	5910-	503-000-B2P0-28R	0130-0006
C15	7-3-3	5910-	315-000-C0G0-100D	0150-0009
C16	7-2-29	5910-	503-000-D2P-033R	0130-0001
C17	7-2-17	5910-	D32452	0180-0025
C19	7-2-54	5910-	160P10494	0160-0013
C2	7-6-1	5910-	160P47396	0160-0005
C20	7-5-2	5910-	148P47491	0170-0064
C22	7-4-10	5910-	CM20B681K	0140-0007
C23	7-2-54	5910-	160P10494	0160-0013
C24	7-2-75	5910-	160P27296	0160-0044
C25	7-2-39	5910-	29C214A3-H-1038	0150-0012
C26	7-4-13	5910-	CM15E680K	0140-0025
C28	7-2-47	5910-	148P22394	0170-0063
C29	7-2-39	5910-	29C214A3-H-1038	0150-0012
C30	7-2-17	5910-	D32452	0180-0025
C31	7-5-2	5910-	148P47491	0170-0064
C32	7-2-1	5910-	663UW20504	0170-0002
C33	7-2-1	5910-	663UW20504	0170-0002
C34 D, H02	7-2-3	5910-	30D120A1	0180-0063
C34 H, L	7-2-3	5910-	30D133A1	0180-0033
C35	7-2-39	5910-	29C214A3-H-1038	0150-0012
C36	7-2-34	5910-	PKM 4P5	0160-0024
C39	7-2-20	5910-	D27390	0180-0028
C4	7-6-8	5910-	503-000-C0P0-10R	0130-0003
C5	7-6-5	5910-	CM35E472J	0140-0084
DS1	7-1-7	6240-	12	2140-0012
F1	7-2-71	5920-	MDL-1	2110-0007
L1	7-4-14	5950-	42 μ H-10%-PHENOLIC FORM	9140-0040
L10	7-5-6	5950-	400D-60A	400D-60A
L11	7-5-6	5950-	400D-60A	400D-60A
M1 D, H02	7-1-11	6625-	1120-0005	1120-0005
M1 H	7-1-11	6625-	1120-0301	1120-0301
M1 L	7-1-11	6625-	1120-0098	1120-0098
P1 D, H, L	7-2-25	6145-	CS-9941/PH151/7.5 FT	8120-0050
P1 H02	7-2-25	6145-	H02-400D-PWR CORD	H02-400D-PWR CORD
R1	7-2-55	5905-	RC32GF114J	0689-1145
R100	7-6-4	5905-	DC-1-10K	0730-0029
R101	7-6-3	5905-	2100-0151	2100-0151
R102	7-2-62	5905-	RC20GF825K	0687-8251

REFERENCE DESIGNATION	FIGURE AND INDEX NUMBER	CLASS CODE OR STOCK NUMBER	MFR. OR MIL. PART NUMBER	H-P PART NUMBER
R103	7-2-61	5905-	RC20GF225K	0687-2251
R104	7-5-3	5905-	400K-26F	400D-26F
R105	7-5-5	5905-	400D-26C	400D-26C
R106	7-5-9	5905-	DC-1/2C-40	0727-0018
R107	7-5-4	5905-	2100-0108	2100-0108
R108	7-5-3	5905-	400D-26F	400D-26F
R110	7-3-2	5905-	RC20GF153K	0687-1531
R111	7-3-4	5905-	400D-26G	400D-26G
R112	7-3-4	5905-	400D-26G	400D-26G
R113	7-3-4	5905-	400D-26G	400D-26G
R114	7-3-4	5905-	400D-26G	400D-26G
R115	7-3-4	5905-	400D-26G	400D-26G
R116	7-3-4	5905-	400D-26G	400D-26G
R117	7-2-59	5905-	RC42GF682K	0693-6821
R118	7-2-18	5905-	2100-0080	2100-0080
R119	7-2-19	5905-	2100-0136	2100-0136
R120	7-2-41	5905-	RC32GF224K	0690-2241
R121	7-2-42	5905-	RC32GF2R7K	0699-0005
R122	7-2-42	5905-	RC32GF2R7K	0699-0005
R20	7-2-56	5905-	RC42GF822K	0693-8221
R21	7-2-50	5905-	RC32GF473K	0690-4731
R22	7-2-56	5905-	RC42GF822K	0693-8221
R23	7-2-66	5905-	N25-8. 2K	0761-0001
R24	7-2-40	5905-	RC20GF470K	0687-4701
R27	7-5-7	5905-	CS-2-12S	0813-0009
R30	7-2-67	5905-	RC20GF125K	0687-1251
R31	7-2-40	5905-	RC20GF470K	0687-4701
R32	7-2-50	5905-	RC32GF473K	0690-4731
R33	7-4-12	5905-	RC42GF273K	0693-2731
R34	7-4-12	5905-	RC42GF273K	0693-2731
R35	7-4-11	5905-	RC32GF242J	0689-2425
R36	7-2-73	5905-	RC20GF335K	0687-3351
R37	7-2-44	5905-	RC20GF275K	0687-2751
R38	7-2-43	5905-	RC20GF561K	0687-5611
R39	7-2-46	5905-	RC20GF104J	0687-1041
R4	7-6-9	5905-	DC-1-10. 31M	0730-0143
R40	7-2-40	5905-	RC20GF470K	0687-4701
R41	7-2-50	5905-	RC32GF473K	0690-4731
R42	7-4-12	5905-	RC42GF273K	0693-2731
R43	7-4-12	5905-	RC42GF273K	0693-2731
R44	7-4-11	5905-	RC32GF242J	0689-2425
R47	7-2-43	5905-	RC20GF561K	0687-5611
R48	7-2-49	5905-	RC20GF684K	0687-6841
R49	7-2-40	5905-	RC20GF470K	0687-4701
R50	7-2-50	5905-	RC32GF473K	0687-4731
R51	7-2-53	5905-	RC32GF332K	0690-3321
R52	7-2-51	5905-	RC42GF103K	0693-1031
R53	7-5-10	5905-	RC20GF511J	0686-5115
R54	7-5-1	5905-	RC32GF510J	0689-5105
R55	7-4-7	5905-	RC42GF184K	0693-1841
R56	7-4-6	5905-	RC32GF563K	0690-5631
R57	7-2-48	5905-	C-10-6. 3K	0816-0017
R58	7-4-5	5905-	RC32GF124K	0690-1241
R59	7-4-8	5905-	RC32GF334K	0690-3341
R6A	7-6-6	5905-	RC20GF100K	0687-1001
R6B	7-6-6	5905-	RC20GF100K	0687-1001
R6C	7-6-7	5905-	RC20GF560K	0687-5601
R60	7-2-74	5905-	RC32GF183K	0690-1831
R61	7-4-1	5905-	RC32GF683K	0690-6831
R62	7-4-4	5905-	DC-1-166K	0730-0076

REFERENCE DESIGNATION	FIGURE AND INDEX NUMBER	CLASS CODE OR STOCK NUMBER	MFR. OR MIL. PART NUMBER	H-P PART NUMBER
R63	7-4-2	5905-	RC20GF104K	0687-1041
R64	7-4-3	5905-	DC-1-90.5K	0730-0065
R66	7-2-68	5905-	2100-0077	2100-0077
R67	7-2-36	5905-	RC20GF471K	0687-4711
R68	7-2-69	5905-	RC32GF100K	0690-1001
R7	7-2-41	5905-	RC32GF224K	0690-2241
R83	7-2-37	5905-	RC20GF474K	0687-4741
R85	7-2-37	5905-	RC20GF474K	0687-4741
R86	7-6-2	5905-	RC20GF470K	0687-4701
R9	7-2-36	5905-	RC20GF471K	0687-4711
S1	7-3-6	5930-	3100-0251	3100-0251
S2	7-1-9	5930-	80994-H	3101-0001
T1	7-2-26	5950-	9100-0050	9100-0050
V1	7-2-12	5960-	6CB6	5080-0621
V2	7-2-8	5960-	6CB6	1923-0028
V3	7-2-8	5960-	6CB6	1923-0028
V4	7-2-8	5960-	6CB6	1923-0028
V5	7-2-8	5960-	6CB6	1923-0028
V6	7-2-21	5960-	6AX5GT	1930-0014
V7	7-2-10	5960-	12B4	1921-0010
V8	7-2-11	5960-	6U8	1933-0004
V9	7-2-9	5960-	5651	1940-0001
XDS1	7-1-8	6250-	2020-AE	1450-0022
XF1	7-2-72	5920-	342014	1400-0084
XV1	7-2-15	5935-	316PH-3702	1200-0009
XV2	7-2-15	5935-	316PH-3702	1200-0009
XV3	7-2-15	5935-	316PH-3702	1200-0009
XV4	7-2-15	5935-	316PH-3702	1200-0009
XV5	7-2-15	5935-	316PH-3702	1200-0009
XV6	7-2-23	5935-	51A12272	1200-0020
XV7	7-2-16	5935-	44F-16388	1200-0008
XV8	7-2-16	5935-	44F-16388	1200-0008
XV9	7-2-15	5935-	316PH-3702	1200-0009

APPENDIX **CODE LIST OF MANUFACTURERS (Sheet 1 of 2)**

The following code numbers are from the Federal Supply Code for Manufacturers Cataloging Handbooks H4-1 (Name to Code) and H4-2 (Code to Name) and their latest supplements. The date of revision and the date of the supplements used appear at the bottom of each page. Alphabetical codes have been arbitrarily assigned to suppliers not appearing in the H4 handbooks.

Code No.	Manufacturer	Address	Code No.	Manufacturer	Address	Code No.	Manufacturer	Address	Code No.	Manufacturer	Address
00000	U.S.A. Common	Any supplier of U.S.	07149	Filtron Corp.	New York, N.Y.	49956	Raytheon Company	Lexington, Mass.	74970	E.F. Johnson Co.	Waco, Minn.
00136	McCoy Electronics	Mount Holly Springs, Pa.	07233	Cinch-Graphix Co.	City of Industry, Calif.	52080	Rowan Controller Co.	Baltimore, Md.	75042	International Resistance Co.	Philadelphia, Pa.
00213	Sage Electronics Corp.	Rochester, N.Y.	07261	Avnet Corp.	Los Angeles, Calif.	63743	Ward Leonard Electric	St. Vernon, N.Y.	75173	Jones, Howard B., Division	Chicago, Ill.
00334	Humidair Co.	Colton, Calif.	07263	Fairchild Semiconductor Corp.	Mountain View, Calif.	64294	Shallcross Mfg. Co.	Solna, N.C.	75378	James Knights Co.	Sandwich, Ill.
00335	Westrex Corp.	New York, N.Y.	07322	Minnesota Rubber Co.	Minneapolis, Minn.	55026	Swapon Electric Co.	Chicago, Ill.	75382	Kulka Electric Corporation	St. Vernon, N.Y.
00373	Garlock Packing Co.	Camden, N.J.	07387	The Birch Corp.	Los Angeles, Calif.	55933	Sonotone Corp.	Elmsford, N.Y.	75818	Lenz Electric Mfg. Co.	Chicago, Ill.
00656	Aerovox Corp.	New Bedford, Mass.	07700	Technical Wire Products	Springfield, N.J.	56137	Spaulding Fibre Co., Inc.	Tonawanda, N.Y.	75915	Littlefuse Inc.	Des Plaines, Ill.
00779	Amp, Inc.	Harrisburg, Pa.	07910	Continental Device Corp.	Hawthorne, Calif.	56289	Sprague Electric Co.	North Adams, Mass.	76005	Lord Mfg. Co.	Erie, Pa.
00781	Aircraft Radio Corp.	Boonton, N.J.	07933	Rheem Semiconductor Corp.	Mountain View, Calif.	59446	Telex, Inc.	St. Paul, Minn.	76210	C.W. Marwedel	San Francisco, Calif.
00815	Northern Engineering Laboratories, Inc.	Burlington, Wis.	07966	Shockley Semi-Conductor Laboratories	Palo Alto, Calif.	59730	Thomas & Betts Co.	Elizabeth 1, N.J.	76433	Micronal Electronic Mfg. Corp.	Brooklyn, N.Y.
00853	Sangamo Electric Company, Ordil Division (Capacitors)	Marion, Ill.	07980	Boonton Radio Corp.	Boonton, N.J.	60741	Tripplett Electrical Inc.	Bluffton, Ohio	76487	James Millen Mfg. Co., Inc.	Malden, Mass.
00866	Goe Engineering Co.	Los Angeles, Calif.	08145	U.S. Engineering Co.	Los Angeles, Calif.	61775	Union Switch and Signal, Div. of Westinghouse Air Brake Co.	Swissvale, Pa.	76493	J.W. Miller Co.	Los Angeles, Calif.
00891	Call E. Holmes Corp.	Los Angeles, Calif.	08358	Burgess Battery Co.	Niagara Falls, Ontario, Canada.	62119	Universal Electric Co.	Owosso, Mich.	76530	Monadnock Mills	San Leandro, Calif.
01021	Allen Bradley Co.	Milwaukee, Wis.	08717	Sloan Company	Barbours, Calif.	63743	Ward-Leonard Electric Co.	St. Vernon, N.Y.	76545	Mueller Electric Co.	Cleveland, Ohio.
01255	Litton Industries, Inc.	Beverly Hills, Calif.	08718	Cannon Electric Co., Phoenix Div.	Phoenix, Ariz.	64959	Western Electric Co., Inc.	New York, N.Y.	76854	Oak Manufacturing Co.	Crystal Lake, Ill.
01281	TRW Semiconductors, Inc.	Lamdale, Calif.	08792	CBS Electronics Semiconductor Operations, Div. of C.B.S., Inc.	Lowell, Mass.	65092	Western Ind. Div. of Daystrom, Inc.	Newark, N.J.	77068	Bendix Pacific Division of Bendix Corp.	Mo. Hollywood, Calif.
01295	Trans Instruments, Inc.	Dallas, Texas	08894	Mc-Rain	Indianapolis, Ind.	66295	Wittek Manufacturing Co.	Chicago 23, Ill.	77075	Pacific Metals Co.	San Francisco, Calif.
01349	The Alliance Mfg. Co.	Indianapolis, Ind.	09026	Babcock Relays, Inc.	Costa Mesa, Calif.	66346	Wolensak Optical Co.	Rochester, N.Y.	77221	Phasston Instrument and Electronic Co.	South Pasadena, Calif.
01561	Chassis-Trak Corp.	Indianapolis, Ind.	09134	Texas Capacitor Co.	Houston, Texas	70276	Allen Mfg. Co.	Hartford, Conn.	77250	Phoell Mfg. Co.	Chicago, Ill.
01589	Pacific Relays, Inc.	Van Nuys, Calif.	09145	Aluma Electronics	San Valley, Calif.	70309	Allen Control Co., Inc.	New York, N.Y.	77252	Philadelphia Steel and Wire Corp.	Philadelphia, Pa.
01930	Amerock Corp.	Rockford, Ill.	09250	Electro Assemblies, Inc.	Chicago, Ill.	70319	Allmetal Screw Prod. Co., Inc.	Garden City, N.Y.	77342	Potter and Brumfield, Div. of American Machine and Foundry	Princeton, Ind.
01961	Pulse Engineering Co.	Santa Clara, Calif.	09569	Mallory Battery Co. of Canada, Ltd.	Toronto, Ontario, Canada.	70485	Atlantic India Rubber Works, Inc.	Chicago, Ill.	77630	Radio Condenser Co.	Camden, N.J.
02114	Ferrocube Corp. of America	Saugerties, N.Y.	09568	The Bristol Co.	Waterbury, Conn.	70563	Asperite Co., Inc.	New York, N.Y.	77638	Radio Receptor Co., Inc.	Brooklyn, N.Y.
02286	Cole Mfg. Co.	Palo Alto, Calif.	09664	The Bristol Co.	Waterbury, Conn.	70903	Belden Mfg. Co.	Chicago, Ill.	77764	Resistance Products Co.	Harrisburg, Pa.
02660	Amphenol-Borg Electronics Corp.	Chicago, Ill.	10214	General Transistor Western Corp.	Los Angeles, Calif.	70998	Bird Electronic Corp.	Cleveland, Ohio	77969	Rubbercraft Corp. of Calif.	Torrance, Calif.
02735	Radio Corp. of America, Semiconductor and Materials Div.	Somerville, N.J.	10411	Ti-Tal, Inc.	Berkeley, Calif.	71002	Bimach Radio Co.	New York, N.Y.	78189	Shakeproof Division of Illinois Tool Works	Elgin, Ill.
02771	Vocaline Co. of America, Inc.	Old Saybrook, Conn.	10646	Carborundum Co.	Niagara Falls, N.Y.	71041	Boston Gear Works Div. of Murray Co. of Texas	Quincy, Mass.	78283	Signal Indicators Corp.	New York, N.Y.
02777	Hopkins Engineering Co.	San Fernando, Calif.	11236	CTS of Berne, Inc.	Berne, Ind.	71218	Bud Radio Inc.	Cleveland, Ohio	78290	Sluthers-Dunn Inc.	Chicago, Ill.
03508	G.E. Semiconductor Products Dept.	Syracuse, N.Y.	11273	Chicago Telephone of California, Inc.	So. Pasadena, Calif.	71286	Castel Fastener Corp.	Paramus, N.J.	78452	Thompson-Bramer & Co.	Chicago, Ill.
03705	Apex Machine & Tool Co.	Dayton, Ohio	11312	Microwave Electronics Corp.	Palo Alto, Calif.	71313	Allen D. Cardwell Electronic Prod. Corp.	Plainville, Conn.	78471	Tilly Mfg. Co.	San Francisco, Calif.
03797	Eldemco Corp.	El Monte, Calif.	11354	Duncan Electronic, Inc.	Santa Ana, Calif.	71400	Bussmann Fuse Div. of McGraw-Hill	St. Louis, Mo.	78488	Stackpole Carbon Co.	St. Marys, Pa.
03877	Transistor Electronic Corp.	Wakfield, Mass.	11711	General Instrument Corporation Semiconductor Division	Newark, N.J.	71436	Chicago Condenser Corp.	Chicago, Ill.	78493	Standard Thomas Corp.	Walham, Mass.
03888	Pyrofilm Resistor Co.	Morristown, N.J.	11717	Imperial Electronic, Inc.	Buena Park, Calif.	71450	CTS Corp.	Elkhart, Ind.	78553	Tienman Products, Inc.	Cleveland, Ohio
03954	Air Marine Motors, Inc.	Los Angeles, Calif.	11870	Melbels, Inc.	Palo Alto, Calif.	71468	Cannex Engineering Co.	Los Angeles, Calif.	78790	Transformer Engineers	Pasadena, Calif.
04009	Arrow, Hart and Hegeman Elect. Co.	Hartford, Conn.	12697	Klipspring Mfg. Co.	Dover, N.H.	71471	Cinema Electronic Co.	Barbours, Calif.	78947	Unicite Corp.	Newtownville, Mass.
04062	Elmenco Products Co.	New York, N.Y.	12859	Rippon Electric Co., Ltd.	Tokyo, Japan	71482	C.P. Clare & Co.	Chicago, Ill.	79251	Veeder Root, Inc.	Hartford, Conn.
04222	H-Q Division of Aerovox	Myrtle Beach, S.C.	12930	Delta Semiconductor Inc.	Newport Beach, Calif.	71590	Central Div. of Globe Union Inc.	Milwaukee, Wis.	79252	Wenco Mfg. Co.	Chicago, Ill.
04298	Elgin National Watch Co., Electronics Division	Burbank, Calif.	13103	Thermolloy	Dallas, Texas	71700	The Cornish Wire Co.	New York, N.Y.	79727	Continental-Wert Electronics Corp.	Philadelphia, Pa.
04404	Dynec Division of Hewlett-Packard Co.	Palo Alto, Calif.	13396	Telefunken (G.M.B.H.)	Hannover, Germany	71744	Chicago Miniature Lamp Works	Chicago, Ill.	79963	Zienick Mfg. Corp.	New Rochelle, N.Y.
04651	Sylvania Electric Prods., Inc.	Mountain View, Calif.	13835	Midland Mfg. Co.	Kansas City, Kansas	71753	A.O. Smith Corp., Crowley Div.	West Orange, N.J.	80031	Mecro Division of Sessions Clock Co.	Morristown, N.J.
04713	Motorola, Inc., Semiconductor Prod. Div.	Phoenix, Arizona	14099	Sea-Tech	Newbury Park, Calif.	71785	Cinch Mfg. Corp.	Chicago, Ill.	80120	Schneider Alloy Products	Elizabeth, N.J.
04732	Filtron Co., Inc., Western Div.	Calver City, Calif.	14193	Calif. Resistor Corp.	Santa Monica, Calif.	71984	Dow Corning Corp.	Midland, Mich.	80130	Times Facsimile Corp.	New York, N.Y.
04733	Automatic Electric Co.	Northlake, Ill.	14298	American Components, Inc.	Coshohocken, Pa.	72092	Eitel-McCullough, Inc.	San Bruno, Calif.	80131	Electronic Industries Association	Any brand
04777	Automatic Electric Sales Corp.	Northlake, Ill.	14655	Cornell Dubilier Elec. Corp.	So. Plainfield, N.J.	72136	Electro Motive Mfg. Co., Inc.	Williamson, Conn.	80207	Unimas Switch, Div. of W.L. Massey Corp.	Wallingford, Conn.
04796	Sequora Wire & Cable Co.	Redwood City, Calif.	14660	Williams Mfg. Co.	San Jose, Calif.	72167	Colo Coil Co., Inc.	Providence, R.I.	80223	United Transformer Corp.	New York, N.Y.
04811	Precision Coil Spring Co.	El Monte, Calif.	15009	The Davies Co.	Livingston, N.J.	72354	John E. Fast & Co.	Chicago, Ill.	80248	Orford Electric Corp.	Chicago, Ill.
04870	P. M. Motor Company	Chicago 44, Ill.	16037	Source Pine Mica Co.	Spencer, N.C.	72556	General Ceramics Corp.	Keasbey, N.J.	80294	Bouns Laboratories, Inc.	Riverside, Calif.
05006	Twentieth Century Plastics, Inc.	Los Angeles, Calif.	16352	Computer Diode Corp.	Lodi, N.J.	72699	General Instrument Corp., Semiconductor Div.	Newark, N.J.	80411	Acto Div. of Robertshaw Fulton Controls Co.	Columbus 16, Ohio
05277	Westinghouse Electric Corp., Semi-Conductor Dept.	Youngwood, Pa.	16688	De Jer-Amco Corporation	Long Island City 1, N.Y.	72758	Grand-Hopkins	Oakland, Calif.	80486	All Star Products Inc.	Delfino, Ohio
05347	Ultratronics, Inc.	San Mateo, Calif.	16758	Delco Radio Div. of G.M. Corp.	Kokomo, Ind.	72765	Drake Mfg. Co.	Chicago, Ill.	80509	Avery Adhesive Label Corp.	Monrovia, Calif.
05593	Humitronic Engineering Co.	Sunnyvale, Calif.	18873	E.C. DePost and Co., Inc.	Wilmington, Del.	72825	Hugh H. Eby Inc.	Philadelphia, Pa.	80583	Hammerlund Co., Inc.	New York, N.Y.
05624	Barber Colman Co.	Rockford, Ill.	19315	Eclipse Pioneer, Div. of Bendix Aviation Corp.	Teterboro, N.J.	72928	Gudeanu Co.	Chicago, Ill.	80640	Stevens, Arnold, Co., Inc.	Boston, Mass.
05728	Triflon Optical Co.	Roslyn Heights, Long Island, N.Y.	19500	Thomas A. Edison Industries, Div. of McGraw-Edison Co.	West Orange, N.J.	72964	Robert M. Hadley Co.	Los Angeles, Calif.	81030	International Instruments, Inc.	New Haven, Conn.
05729	Metropolitan Telecommunications Corp.	Brooklyn, N.Y.	19701	Electra Manufacturing Co.	Kansas City, Mo.	72982	Erie Resistor Corp.	Erie, Pa.	81073	Grayhill Co.	LaGrange, Ill.
05783	Stewart Engineering Co.	Santa Cruz, Calif.	20183	Electronic Tube Corp.	Philadelphia, Pa.	73061	Hansen Mfg. Co., Inc.	Princeton, Ind.	81095	Triad Transducer Corp.	Venice, Calif.
05820	Wakefield Engineering Inc.	Wakefield, Mass.	21276	Executive, Inc.	New York, N.Y.	73138	Helipot Div. of Beckman Instruments, Inc.	Fullerton, Calif.	81312	Winchester Electronics Co., Inc.	Norwalk, Conn.
06004	The Bassick Co.	Bridgeport, Conn.	21520	Fanshell Metallurgical Corp.	Mo. Chicago, Ill.	73293	Hughes Products Division of Hughes Aircraft Co., Div. of North American Phillips Co., Inc.	Newport Beach, Calif.	81349	Military Specification	-----
06175	Bausch and Lomb Optical Co.	Rochester, N.Y.	21635	The Fafnir Bearing Co.	New Britain, Conn.	73445	American Philips Co., Inc.	Hicksville, N.Y.	81415	Wikor Products, Inc.	Cleveland, Ohio
06402	E.T.A. Products Co. of America	Chicago, Ill.	21646	Federal Telephone and Radio Corp.	Clifton, N.J.	73490	Beckman Helipot Corp.	So. Pasadena, Calif.	81453	Raytheon Mfg. Co., Industrial Components	Newton, Mass.
06440	Anton Electronic Hardware Co. Inc.	New Rochelle, N.Y.	24445	General Electric Co.	Schenectady, N.Y.	73506	Bradley Semiconductor Corp.	Hawden, Conn.	81483	International Rectifier Corp.	El Segundo, Calif.
06555	Beede Electrical Instrument Co., Inc.	Penacook, N.H.	24655	G.E. Lamp Division	Mela Park, Cleveland, Ohio	73559	Carling Electric, Inc.	Hartford, Conn.	81541	The Airco Products Co.	Cambridge, Mass.
06571	U.S. Sensor Division of Nuclear Corp. of America	Phoenix, Arizona	24656	Gries Reproductor Corp.	New Rochelle, N.Y.	73682	George K. Garrett Co., Inc.	Philadelphia, Pa.	81860	Barry Controls, Inc.	Watertown, Mass.
06812	Torrington Mfg. Co., West Div.	Van Nuys, Calif.	24657	Grobel File Co. of America, Inc.	Carlsbad, N.J.	73734	Federal Screw Prod. Co.	Chicago, Ill.	82042	Carter Parts Co.	Skokie, Ill.
07115	Corning Glass Works	Corning, N.Y.	24658	Hamilton Watch Co.	Lancaster, Pa.	73743	Fischer Special Mfg. Co.	Cincinnati, Ohio	82142	Jeffers Electronics Division of Speer Carbon Co.	Du Bois, Pa.
07126	Digital Co.	Pasadena, Calif.	24659	Hewlett-Packard Co.	Palo Alto, Calif.	73793	The General Industries Co.	Elyria, Ohio	82170	Allen B. DuMont-Labs, Inc.	Clifton, N.J.
07137	Transistor Electronics Corp.	Minneapolis, Minn.	24660	Hewlett-Packard Co.	Palo Alto, Calif.	73846	Goshen Stamping & Tool Co.	Goshen, Ind.	82209	Maguire Industries, Inc.	Greenwich, Conn.
07138	Westinghouse Electric Corp. Electronic Tube Div.	Elmhurst, N.Y.	24661	Hewlett-Packard Co.	Palo Alto, Calif.	73899	JFD Electronics Corp.	Brooklyn, N.Y.	82219	Sylvania Electric Prod. Inc.	Emporium, Pa.
			24662	Hewlett-Packard Co.	Palo Alto, Calif.	73905	Jennings Radio Mfg. Co.	San Jose, Calif.	82376	Astron Co.	East Newark, N.J.
			24663	Hewlett-Packard Co.	Palo Alto, Calif.	74276	Signalite Inc.	Neptune, N.J.	82389	Switchcraft, Inc.	Chicago, Ill.
			24664	Hewlett-Packard Co.	Palo Alto, Calif.	74455	J.H. Wynn, and Sons	Winchester, Mass.	82647	Metals and Controls, Inc., Div. of Texas Instruments, Inc.	Spencer, Mass.
			24665	Hewlett-Packard Co.	Palo Alto, Calif.	74861	Industrial Condenser Corp.	Chicago, Ill.			
			24666	Hewlett-Packard Co.	Palo Alto, Calif.	74868	R.F. Products Division of Amphenol-Borg Electronics Corp.	Danbury, Conn.			

APPENDIX **CODE LIST OF MANUFACTURERS (Sheet 2 of 2)**

Code No.	Manufacturer	Address	Code No.	Manufacturer	Address	Code No.	Manufacturer	Address	Code No.	Manufacturer	Address
82866	Research Products Corp.	Madison, Wis.	89636	Carter Parts Div. of Economy Baler Co.	Chicago, Ill.	95263	Leecraft Mfg. Co., Inc.	New York, N.Y.	THE FOLLOWING H-P VENDORS HAVE NO NUMBER ASSIGNED IN THE LATEST SUPPLEMENT TO THE FEDERAL SUPPLY CODE FOR MANUFACTURERS HANDBOOK.		
82877	Roton Manufacturing Co., Inc.	Woodstock, N.Y.	89665	United Transformer Co.	Chicago, Ill.	95264	Lenco Electronics, Inc.	Burbank, Calif.			
82893	Vecor Electronic Co.	Glendale, Calif.	90179	U.S. Rubber Co., Mechanical Goods Div.	Passaic, N.J.	95265	National Coil Co.	Sheridan, Wyo.			
83053	Western Washer Mfr. Co.	Los Angeles, Calif.	90970	Bearing Engineering Co.	San Francisco, Calif.	95275	Vitramon, Inc.	Bridgeport, Conn.			
83058	Carr Fastener Co.	Cambridge, Mass.	91260	Conner Spring Mfg. Co.	San Francisco, Calif.	95348	Gordas Corp.	Bloomfield, N.J.	C0000 JFD Electronics Corp. Van Nuys, Calif. G0000 Tranex Company Mountain View, Calif. I0000 Western Devices, Inc. Inglewood, Calif. J0000 Winchester Electronics, Inc. Santa Monica, Calif.		
83086	New Hampshire Ball Bearing, Inc.	Peterborough, N.H.	91245	Miller Dial & Nameplate Co.	El Monte, Calif.	95354	Methode Mfg. Co.	Chicago, Ill.			
83125	Pyramid Electric Co.	Darlington, S.C.	91418	Radio Materials Co.	Chicago, Ill.	95387	Weckesser Co.	Chicago, Ill.			
83148	Electro Cords Co.	Los Angeles, Calif.	91506	Augat Brothers, Inc.	Attleboro, Mass.	96067	Huggins Laboratories	Sunnyvale, Calif.			
83186	Victory Engineering Corp.	Union, N.J.	91637	Dale Electronics, Inc.	Columbus, Nebr.	96095	Hi-Q Division of Aerovox	Clean, N.Y.	C000F Malco Tool and Die Los Angeles, Calif. O000M Western Coil Div. of Automatic Ind., Inc. Redwood City, Calif. O000N Nahn-Bros. Spring Co. San Leandro, Calif. O000P Ty-Car Mfg. Co., Inc. Holliston, Mass. O000W Webster Electronics Co., Inc. New York, N.Y. O000Z Willow Leather Products Corp. Newark, N.J. O00AA British Radio Electronics Ltd. Washington, D.C. O00AB ETA England O00AC Indiana General Corp., Elect. Div. Indiana O00AD Curtis Instrument Inc. Mt. Kisco, N.Y. O00BB Precision Instrument Components Co. Van Nuys, Calif.		
83298	Bendix Corp., Red Bank Div.	Red Bank, N.J.	91662	Elco Corp.	Philadelphia, Pa.	96296	Solar Manufacturing Co.	Chicago, Ill.			
83315	Hubbell Corp.	Mundelein, Ill.	91737	Grenar Mfg. Co., Inc.	Wakefield, Mass.	96330	Carlton Screw Co.	Chicago, Ill.			
83330	Smith, Herman H., Inc.	Brooklyn, N.Y.	91827	K F Development Co.	Redwood City, Calif.	96341	Microwave Associates, Inc.	Burlington, Mass.			
83385	Central Screw Co.	Chicago, Ill.	91929	Minneapolis-Honeywell Regulator Co., Microswitch Div.	Freeport, Ill.	96501	Excel Transformer Co.	Oakland, Calif.			
83501	Gavitt Wire and Cable Co., Div. of Amerace Corp.	Brookfield, Mass.	92180	Tru-Connector Corp.	Peabody, Mass.	97464	Industrial Retaining Ring Co.	Irvington, N.J.			
83594	Burroughs Corp., Electronic Tube Div.	Plainfield, N.J.	92196	Universal Metal Prod., Inc.	Bassett Puente, Calif.	97539	Automatic and Precision Mfg. Co.	Yonkers, N.Y.	Y0000 CBS Electronics, Div. of C.B.S., Inc. Danvers, Mass. Y0001 Reon Resistor Corp. Yonkers, N.Y. Y0002 Axel Brothers Inc. Jamaica, N.Y. Y0003 Rubber Teck, Inc. Gardena, Calif. Y0004 Francis L. Mosley Pasadena, Calif. Y0005 Microdot, Inc. So. Pasadena, Calif. Y0006 Sealectro Corp. Manaroneck, N.Y. Y0007 Carad Corp. Redwood City, Calif. Y0008 General Mills Minneapolis, Minn. Y0009 North Hills Electric Co. Minneapolis, Minn. Y0010 International Electronic Div. of Clevite Corp. Waltham, Mass. Y0011 Columbia Technical Corp. Burbank, Calif. Y0012 Varian Associates New York, N.Y. Y0013 Marshall Industries, Electron Products Division Pasadena, Calif. Y0014 Control Switch Division, Controls Co. of America El Segundo, Calif. Y0015 Delevan Electronics Corp. East Aurora, N.Y. Y0016 Wilco Corporation Indianapolis, Ind. Y0017 Renbrandt, Inc. Boston, Mass. Y0018 Hoffman Semiconductor Div. of Hoffman Electronics Corp. Evanston, Ill. Y0019 Technology Instrument Corp of Calif. Newbury Park, Calif.		
83740	Eveready Battery	New York, N.Y.	92367	Elgeet Optical Co., Inc.	Rochester, N.Y.	97966	CBS Electronics	Yonkers, N.Y.			
83777	Model Eng. and Mfg., Inc.	Huntington, Ind.	92607	Tinsolite Insulated Wire Co.	Tarrytown, N.Y.	97979	Reon Resistor Corp.	Yonkers, N.Y.			
83821	Loyd Scruggs Co.	Festus, Mo.	93332	Sylvania Electric Prod. Inc., Semiconductor Div.	Woburn, Mass.	98141	Axel Brothers Inc.	Jamaica, N.Y.			
84171	Arco Electronics, Inc.	New York, N.Y.	93359	Robbins and Myers, Inc.	New York, N.Y.	98159	Rubber Teck, Inc.	Gardena, Calif.			
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85474	R.M. Bracamonte & Co.	San Francisco, Calif.	94144	Raytheon Mfg. Co., Industrial Components Div., Receiving Tube Operation	Quincy, Mass.	98821	North Hills Electric Co.	Minneapolis, Minn.			
85660	Korled Kords, Inc.	New Haven, Conn.	94145	Raytheon Mfg. Co., Semiconductor Div., California Street Plant	Newton, Mass.	98925	Clevite Transistor Prod. Div. of Clevite Corp.	Waltham, Mass.			
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86579	Precision Rubber Products Corp.	Dayton, Ohio	94197	Curtiss-Wright Corp., Electronics Div.	East Paterson, N.J.	99313	Varian Associates	Palo Alto, Calif.			
86684	Radio Corp. of America, RCA Electron Tube Div.	Harrison, N.J.	94222	Souhco Div. of S. Chester Corp.	Lester, Pa.	99515	Marshall Industries, Electron Products Division	Pasadena, Calif.			
87216	Phlico Corporation (Lansdale Division)	Lansdale, Pa.	94310	Tru Ohm Prod. Div. of Model Engineering and Mfg. Co.	Chicago, Ill.	99707	Control Switch Division, Controls Co. of America	El Segundo, Calif.			
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MODELS 400D/H/L, H02-400D

VACUUM TUBE VOLTMETER

Manual Serial Prefixed: 310- (400D/H02-400D)
313- (400H/L)
(Part No. 400D/H/L-902)

To adapt this manual to instruments with earlier serial numbers check for errata below, and make changes shown in tables.

NOTE

These Manual Backdating Changes make this manual applicable to earlier instruments. Instrument-component values that differ from those in this manual, yet are not listed in the Backdating Changes, should be replaced using the part numbers given in this manual.

Instrument Serial Nos.	Make Manual Changes	Instrument Serial Nos.	Make Manual Changes
(400D/H02-400D) Above 310-45571	Manual applies	(400DR) Above 310-45571	4
(400H/L) Above 313-22177	Manual applies	(400DR) Below 310-45570	1, 4
(400D/H02-400D) Below 310-45570	1	(400HR/LR) Above 313-22177	4
(400H/L) Below 313-22176	1	(400HR/LR) Below 313-22176	1, 4
(400L) Below 048-13256	1, 2	(400HR) Below 017-12026	1, 5
(400H) Below 017-12026	1, 3	(400LR) Below 048-13256	1, 5

CHANGE #1

Section V, Figure 5-10, Voltmeter Schematic Diagram

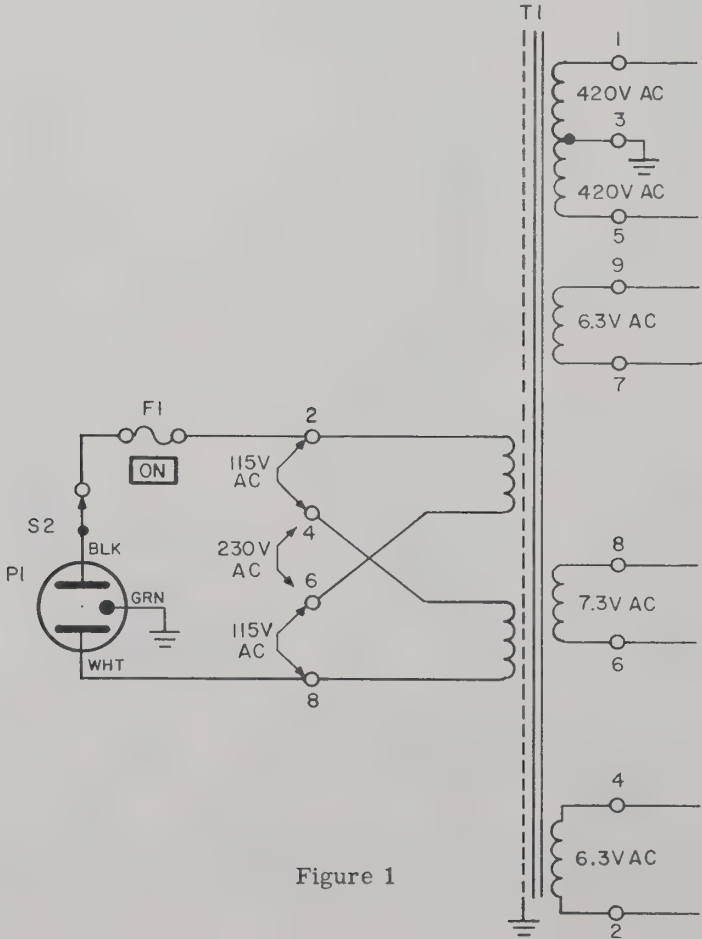


Figure 1

CHANGE #2

Section VII, Figures 7-1-11 and 7-1-14

Multimeter, Replacement: Change  Part No. to read 1120-0081.Panel, Front: Change  Part No. to read 400H-2.

Section VIII, Numerical Indexes

Change MFR. OR MIL. PART NO. 1120-0098 to read 1120-0081.

Change MFR. OR MIL. PART NO. 400H-2A to read 400H-2.

Section IX, Reference Designation Index

Change Reference Designation M1 L MFR. OR MIL. PART NO. and -HP-PART NUMBER to read 1120-0081.

CHANGE #3

Section VII, Figures 7-1-11 and 7-1-14

Multimeter, Replacement: Change  Part No. to read 1120-0048.Panel, Front: Change  Part No. to read 400H-2.

Section VIII, Numerical Indexes

Change MFR. OR MIL. PART NO. 1120-0301 to read 1120-0048.

Change MFR. OR MIL. PART NO. 400H-2A to read 400H-2.


Section IX, Reference Designation Index

Change Reference Designation M1 H MFR. OR MIL. PART NO. and -HP-PART NUMBER to read 1120-0048.


CHANGE #4

Replacement parts common to rack mount instruments (400DR/HR/LR) only:

ADD

Description	 Part No.
Dust Cover	5000-0627
Panel, Front - DR	400D-2R
HR	400H-2B
LR	400L-2B
Bracket, Panel Mtg.	400D-12B
Insulator, Bushing	400D-41A
Bracket, Mtg. (HR/LR)	5020-0243

DELETE

Description	 Part No.
Cabinet Ass'y	400D-44
Panel, Front - D	400D-2
H/L	400H-2A
Bezel	5020-0137

CHANGE #5

Replacement Parts:

Multimeter Replacement: Change  Stock No. to read (HR) 1120-0048; (LR) 1120-0081.Panel, Front: Change  Stock No. to read (HR) 400H-2R; (LR) 400L-2R.

All other additions and deletions in CHANGE #5 apply.



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For assistance of any kind, including help with instruments under warranty, contact your nearest Hewlett-Packard field office for instructions. Give full details of the difficulty and include the instrument model and serial numbers. Service data or shipping instructions will be promptly sent to you. There will be no charge for repair of instruments under warranty, *except transportation charges*. Estimates of charges for non-warranty or other service work will always be supplied, if requested, before work begins.

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On receipt of shipping instructions, forward the instrument prepaid to the destination indicated. You may use the original shipping carton or any strong container. Wrap the instrument in heavy paper or a plastic bag and surround it with three or four inches of shock-absorbing material to cushion it firmly and prevent movement inside the container.

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400D/H/L

VACUUM TUBE VOLTMETER

OPERATING AND SERVICING MANUAL





MANUAL CHANGES

MODEL 400D/H/L

VACUUM TUBE VOLTMETER

ERRATA:

Sect. II Page 4-Subparagraph "C", Amplifier:

Delete all of the information to the end of the section.
Replace with the following:

C. AMPLIFIER

With full scale meter deflection, the amplifier open circuit output is approximately 0.15 volts rms on any range. The Model 400D/H/L thus is useful as an amplifier with input signals less than approximately 0.1 volt. Maximum gain will be obtained with the RANGE switch on the 0.001 volt position. Be careful not to overdrive the amplifier. You should select a range which gives a meter deflection near full scale. Signals more than about 2 times full scale will cause severe distortion. The impedance looking into the OUTPUT terminals is approximately 50 ohms.

The frequency response and voltage calibration of the instrument may be affected by any external load impedance applied to the output terminals. The effect will be greater near the edges of the nominal band pass of the amplifier.

You can quickly check the effect of the applied load:

Observe the meter reading obtained with the output terminals open circuited and then note any shift of reading when the external circuit is connected to the OUTPUT terminals. If this shift is negligible, the measurement is not being affected appreciably by the load. When the nature of the input signal is changed: i.e., a different frequency or band of frequencies is applied, repeat the quick check described above.

12/15/59

Model 400D/H/L - Page 2

ADDENDUM:

For instruments with Serials Prefixed: 001-, the manual for Model 400D, Serial 27971 and above; Model 400H, Serial 6526 and above; Model 400L, Serial 6516 and above, applies with all corrections listed above.

ERRATA:

I1: Change to lamp, incandescent, 6-8V, 2 pin base, GE #12;
-hp- Stock No. 211-78, Mfr., G.E. Lamp Works

P1: Change to power cord; -hp- Stock No. 812-106,
Mfr., Cornish Wire Co.

R65: Delete

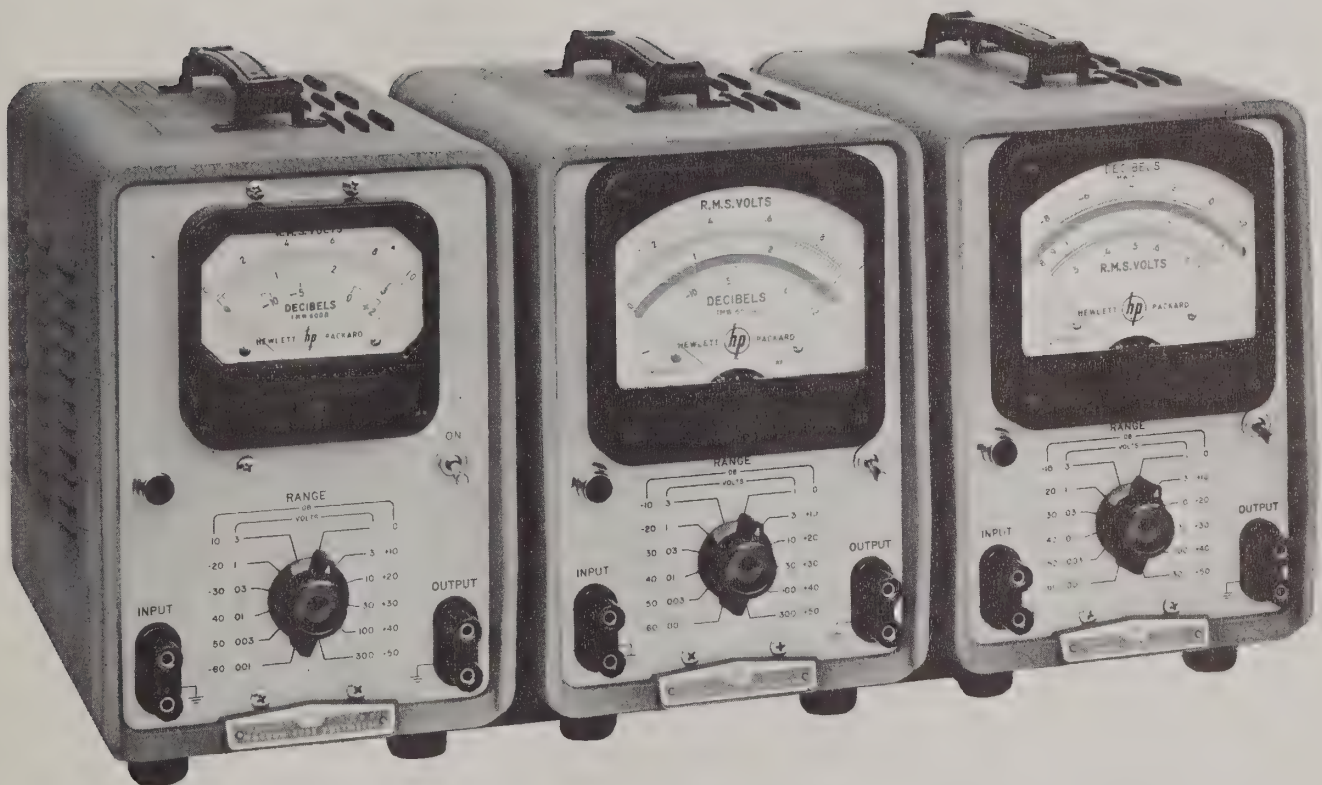
MISC: Jewel for pilot light; -hp- Stock No. 145-23A, Mfr., AD
Lampholder, for 2 pin base; -hp- Stock No. 145-25,
Mfr., AD

OPERATING AND SERVICING MANUAL



MODELS 400D/H/L

VACUUM TUBE VOLTMETERS



Model 400D
Serial 27971 and above

Model 400H
Serial 6526 and above

Model 400L
Serial 6516 and above

SPECIFICATIONS

MODEL 400D/H/L

VOLTAGE RANGE: 0.1 millivolt to 300 volts. Twelve ranges selected with front panel switch.

Full scale readings of:	0.001	0.100	10.00
	0.003	0.300	30.00
	0.010	1.000	100.00
	0.030	3.000	300.00

DECIBEL RANGE: -72 to + 52 db, in 12 ranges.

FREQUENCY RANGE: 10 cps to 4 mc/s.

ACCURACY: At nominal line voltage $\pm 10\%$. Overall accuracy is within:

MODEL 400D: $\pm 2\%$ of full scale, 20 cps to 1 mc;
 $\pm 3\%$ of full scale, 20 cps to 2 mc;
 $\pm 5\%$ of full scale, 10 cps to 4 mc.

MODEL 400H: $\pm 1\%$ of full scale, 50 cps to 500 kc;
 $\pm 2\%$ of full scale, 20 cps to 1 mc;
 $\pm 3\%$ of full scale, 20 cps to 2 mc;
 $\pm 5\%$ of full scale, 10 cps to 4 mc.

MODEL 400L: $\pm 2\%$ of reading or $\pm 1\%$ of full scale whichever is more accurate, 50 cps to 500 kc.

$\pm 3\%$ of reading or $\pm 2\%$ of full scale whichever is more accurate, 20 cps to 1 mc.

$\pm 4\%$ of reading or $\pm 3\%$ of full scale whichever is more accurate, 20 cps to 2 mc.

$\pm 5\%$ of reading 10 cps to 4 mc.

LONG TERM STABILITY: Reduction in G_m of amplifier tubes to 75% of nominal value results in error of less than 0.5%, 20 cps to 1 mc.

CALIBRATION:	MODELS 400D and 400H:	Reads rms value of sine wave. Voltage indication proportional to average value of applied wave. Linear voltage scales 0 to 3.0 and 0 to 1.0; db scale, -12 db to +2 db, based on 0 dbm = 1 mw in 600 ohms; 10 db intervals between ranges.
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MODEL 400L: Calibrated in the rms value of a sine wave. Logarithmic voltage scales 0.3 to 1 and 0.8 to 3. Linear db scale, -10 db to +2 db, based on 0 db = 1 mw in 600 ohms, 10 db intervals between ranges.

INPUT IMPEDANCE: 10 megohms shunted by 15 μf on ranges 1.0 volt to 300 volts; 25 μf on ranges 0.001 volt to 0.3 volt.

SPECIFICATIONS (CONT'D)


MODEL 400D/H/L

AMPLIFIER: Output terminals are provided so voltmeter can be used to amplify small signals or to monitor waveforms under test with an oscilloscope. Output approximately 0.15 volt rms on all ranges with full-scale meter deflection. Amplifier frequency response same as that of voltmeter. Internal impedance approximately 50 ohms over entire frequency range.

POWER SUPPLY: 115/230 volts, $\pm 10\%$, 50/1000 cps, approximately 100 watts.

SIZE: Cabinet Mount: 11-1/2" high, 7-1/2" wide, 12" deep.
Rack Mount: 7" high, 19" wide, 11-3/4" deep.

WEIGHT: Cabinet Mount: 18 lbs.; shipping weight approximately 25 lbs.
Rack Mount: 22 lbs.; shipping weight approximately 35 lbs.

ALSO AVAILABLE:  Model 400D-db, with a special meter face having the db meter scale uppermost to permit greater resolution in db readings.

Contents

SECTION I GENERAL DESCRIPTION

1 - 1	General Description	I - 1
1 - 2	Damage in Transit	I - 1
1 - 3	Power Line Voltage	I - 1
1 - 4	Power Cable	I - 1
1 - 5	Accessories	I - 1

SECTION II OPERATING INSTRUCTIONS

2 - 1	Controls and Terminals	II - 1
2 - 2	Operation	II - 1

SECTION III THEORY OF OPERATION

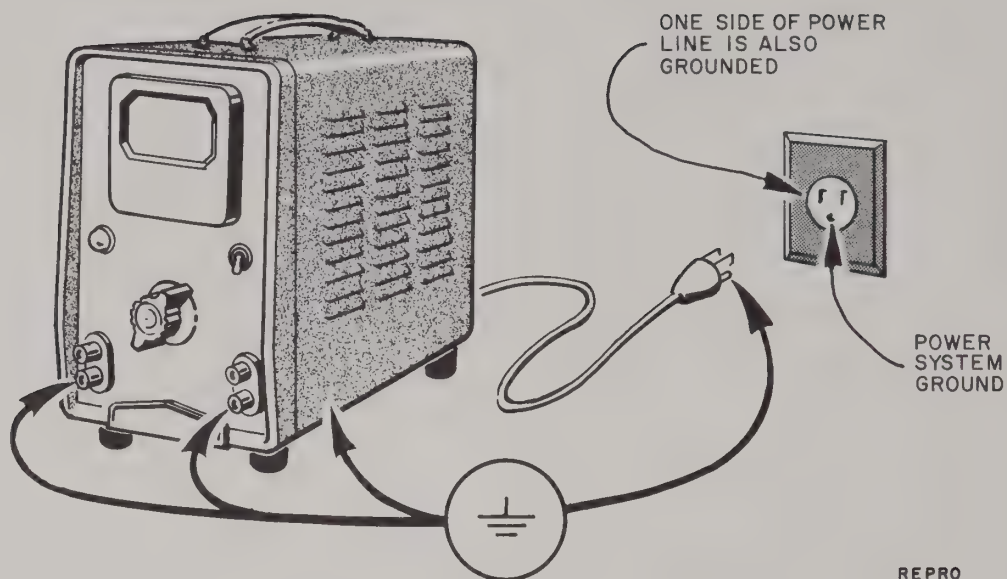
3 - 1	General	III - 1
3 - 2	Input Voltage Divider	III - 1
3 - 3	Amplifier, Rectifier and Meter	III - 2
3 - 4	Power Supply	III - 4

SECTION IV MAINTENANCE

4 - 1	Introductory	IV - 1
4 - 2	Meter Zero Adjustment	IV - 1
4 - 3	Case Removal	IV - 1
4 - 4	Tube and Crystal Diode Replacement	IV - 1
4 - 5	Required Test Equipment	IV - 3
4 - 6	Rapid Performance Check	IV - 5
4 - 7	Complete Adjustment and Test Procedure	IV - 5
4 - 8	Trouble Shooting	IV - 9
4 - 9	Power Supply Trouble Localization	IV - 13
4 - 10	Amplifier Trouble Localization	IV - 13

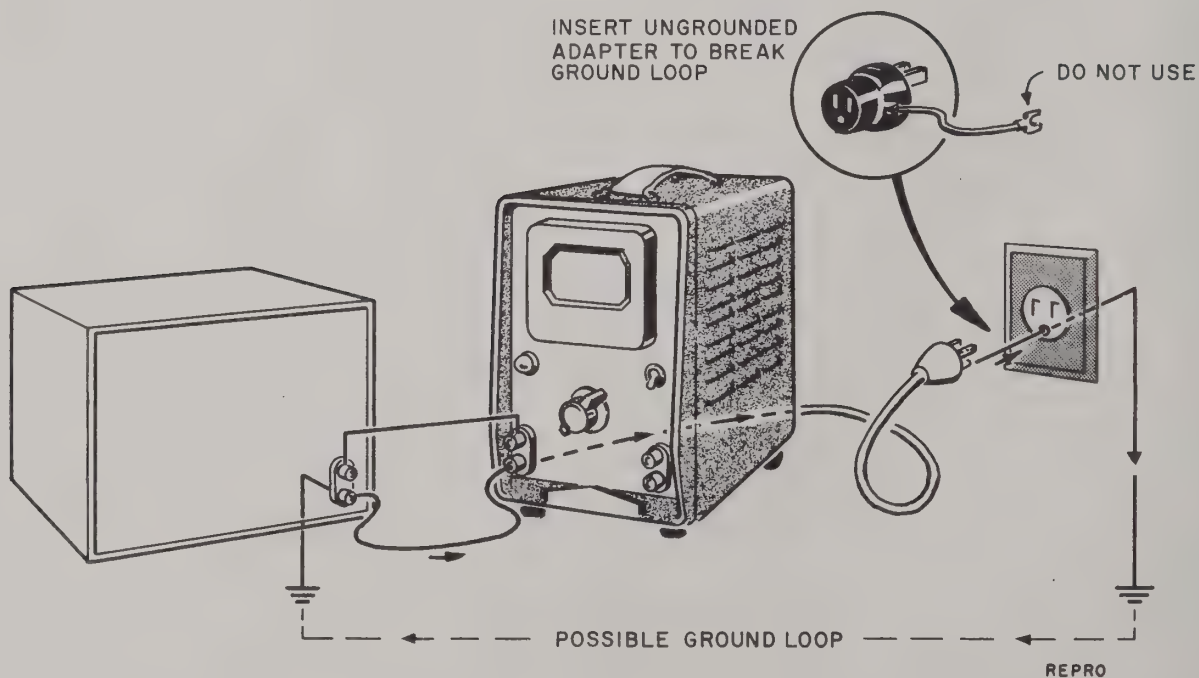
SECTION V TABLE OF REPLACEABLE PARTS

5 - 1	Table of Replaceable Parts	V - 1
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CAUTION

Both the black binding posts and the instrument case will be connected to the power system ground when the instrument is used with the standard NEMA receptacle. Avoid short circuits by connecting only ground potential circuits to the black binding posts.



CAUTION

Ground loops may affect the accuracy of low voltage measurements. Open the loop and restore the accuracy by inserting an ungrounded adapter in the instrument power circuit.

SECTION I

GENERAL DESCRIPTION

1-1 GENERAL DESCRIPTION

This vacuum tube voltmeter is an accurate and sensitive average-responding rms calibrated voltmeter which will measure ac voltages from 0.001 volt full scale to 300 volts full scale over a frequency range of 10 cycles to 4 megacycles. It has an input impedance of 10 megohms, effectively preventing disturbance to circuits under test. The distinctive features of this voltmeter make it valuable for measuring gain, network response, and output level with speed and accuracy. The wide frequency range makes it suitable for audio, rf, and video measurements.

TABLE 1-1. RANGES

Switch Position		Voltage Range	Decibel Range
Volts	db		
.001	-60	0 to 0.001	-72 to -58
.003	-50	0 to 0.003	-62 to -48
.01	-40	0 to 0.01	-52 to -38
.03	-30	0 to 0.03	-42 to -28
.1	-20	0 to 0.1	-32 to -18
.3	-10	0 to 0.3	-22 to - 8
1	0	0 to 1	-12 to + 2
3	+10	0 to 3	- 2 to +12
10	+20	0 to 10	+ 8 to +22
30	+30	0 to 30	+18 to +32
100	+40	0 to 100	+28 to +42
300	+50	0 to 300	+38 to +52

The sensitivity of the voltmeter is sufficient in many instances to measure hum and noise level directly. The voltmeter also may be used as an audio level meter; as a high-gain broadband amplifier to give increased sensitivity to oscilloscopes, bridges, and other equipment requiring additional sensitivity; and to detect nulls.

1-2 DAMAGE IN TRANSIT

If upon initial inspection this instrument is found to be damaged in any way, refer to CLAIM FOR DAMAGE IN SHIPMENT for the necessary instructions.

1-3 POWER LINE VOLTAGE

The instrument is normally supplied wired for 115-volt operation. If it is desired to operate the instrument from a 230-volt source, refer to the transformer conversion data on the schematic diagram for the correct procedure.

Refer to the Table of Replaceable Parts for the correct power line fuse for 230-volt operation.

1-4 POWER CABLE

The three conductor power cable supplied with this instrument is terminated in a polarized three-prong male connector recommended by the National Electrical Manufacturers' Association. The third contact is an offset round pin, added to a standard two-blade connector, which grounds the instrument chassis when used with the appropriate receptacle. To use this NEMA connector in a standard two-contact receptacle, an adapter may be used. The ground connection emerges from the adapter as a short lead which should be connected to a suitable ground for the protection of operating personnel.

1-5 ACCESSORIES

Accessories available for use with the Model 400D/H/L Vacuum Tube Voltmeter are listed below. These accessories are not supplied with the instrument but may be purchased from the Hewlett-Packard Company.

Model AC-60A Line Matching Transformer -
Provides balanced 135 ohm or 600 ohm input to 600 ohm unbalanced output, for measurements on balanced lines.

Terminating Resistance:
600 ohms or 10,000 ohms

Frequency Range:
5 kc to 600 kc

Power Handling Capacity:
+22 dbm (10 volts at 600 ohms)

Balance:
Better than 40 db, entire frequency range

Model AC-60B Line Bridging Transformer -
Provides balanced 600 ohm input to 600 ohm unbalanced output, for measurements on balanced lines.

Terminating Resistance:
600 ohms or 10,000 ohms

Frequency Range:
20 cps to 45 kc

Power Handling Capacity:
+15 dbm (4.5 volts at 600 ohms)

Model 452A Capacitive Voltage Divider -

Division ratio: 1000:1
Accuracy: $\pm 3\%$
Input Capacity: $15\mu\text{f}$, $\pm 1\mu\text{f}$
Maximum voltage rating:
60 cps 25 kv
1 mc 20 kv
20 mc 7 kv
100 kc 22 kv
10 mc 15 kv

Model 454A Capacitive Voltage Divider -

Division Ratio: 100:1
Accuracy: $\pm 3\%$
Frequency Range: 20 cps to 4mc
Input Impedance: 50 megohms shunted with $2.75\mu\text{f}$
Maximum Voltage: 1500 volts

Model 470A through 470F Shunt Resistors -
These shunt resistors adapt the voltmeter for measuring currents as small as 1 microamp full scale.

Accuracy: $\pm 1\%$ to 100 kc, 470A-F
 $\pm 5\%$ to 1 mc, 470A
 $\pm 5\%$ to 4 mc, 470B-F

Maximum power dissipation: 1 watt

<u>Model</u>	<u>Shunt Resistance</u>	<u>Maximum Current</u>
470A	0.1 ohms	3 amps
470B	1.0 ohms	1 amp
470C	10.0 ohms	300 ma
470D	100.0 ohms	100 ma
470E	600.0 ohms	41 ma
470F	1000.0 ohms	30 ma

SECTION II

OPERATING INSTRUCTIONS

2-1 CONTROLS AND TERMINALS

ON -

This toggle switch closes the primary circuit of the power transformer. With the switch ON, the red pilot lamp will glow.

DB VOLTS -

This rotary switch connects the proper multiplier resistors into the circuit for the desired voltage range. The position of the switch indicates 1) the full scale voltage of the range in use and 2) the db level, when the meter pointer is at zero on the DECIBELS scale. Limits of each range are shown in Table 1-1.

INPUT AND OUTPUT TERMINALS -

The two binding posts designated INPUT are connected to the input circuit of the instrument. The two binding posts designated OUTPUT are the output terminals for the amplifier. The lower binding post in each pair, designated G is connected to the chassis. The binding posts will accommodate either a banana plug or wire, and are so arranged that any double banana plug with a 3/4 inch spacing may be used.

CAUTION

The maximum voltage (the sum of the dc voltage and ac peak voltage) applied to the input terminals of the instrument must not exceed 600 volts. Higher voltages will break down the capacitors in the input system of the instrument.

FUSE -

The fuseholder, located on the back of the instrument, contains cartridge fuse, which is in the power transformer primary circuit. Replacement fuses must be of the "Slo-Blo" type as specified in the Table of Replaceable Parts.

2-2 OPERATION

NOTE

When the Model 400D or 400H is turned off the meter pointer should indicate zero. If it does not, refer to the correct zero adjustment procedure in Section IV, paragraph 4-2.

The Model 400L Meter pointer adjustment screw is not connected to anything. The proper adjustment is made by the meter movement manufacturer.

After the Model 400D or 400H is turned on, the meter pointer may show an indication of as much as two scale divisions, principally on the one millivolt range. This effect is normal and does not impair the accuracy of the instrument.

On the lowest three ranges of the instrument the high input impedance coupled with the gain of the amplifier causes the meter needle to be forced against the right-hand stop of the meter when the input terminals are unshielded. This condition is normal and is caused by stray voltages in the vicinity of the instrument.

If measurements are made from a high-impedance source, hum pick-up can affect the meter indication because of the high impedance of both the source and the voltmeter. Shielded leads will reduce pick-up, although they will cause an increase in the capacity shunted across the source, with the possibility of excessive circuit loading.

In order to maintain accuracy of measurement, it must be kept in mind that the instrument is an average-responding device but that the meter is calibrated in terms of the rms voltage of a pure sine wave. If the waveform of the voltage being measured contains appreciable harmonic voltages or other spurious voltages, the meter indication will deviate from the true rms value on the order indicated by Table 2-1.

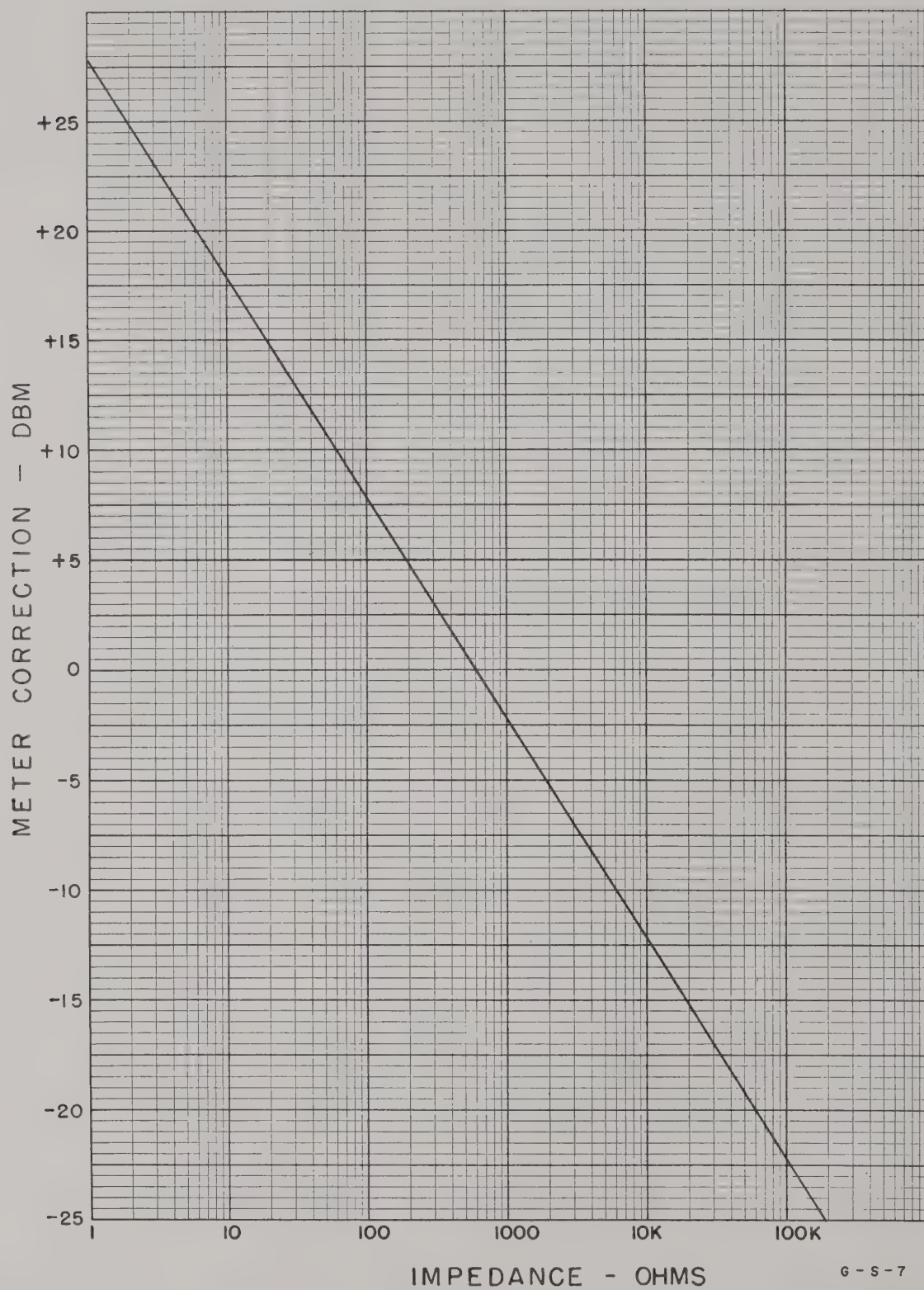


Figure 2-1. Model 400D/H/L Impedance Correction Graph

TABLE 2-1. EFFECT OF HARMONICS ON MODEL 400D/H/L VOLTAGE MEASUREMENTS

Input Voltage Characteristics	True RMS Value	Value Indicated by Model 400D/H/L
Fundamental = 100	100	100
Fundamental +10% 2nd harmonic	100.5	100
Fundamental +20% 2nd harmonic	102	100-102
Fundamental +50% 2nd harmonic	112	100-110
Fundamental +10% 3rd harmonic	100.5	96-104
Fundamental +20% 3rd harmonic	102	94-108
Fundamental +50% 3rd harmonic	112	90-116

a. Voltage Measurements -

1) With the instrument plugged into a power source of specified voltage and frequency, and the toggle switch at ON, allow the instrument about five minutes to reach a state of stable operation.

2) Set the DB VOLTS (range) switch to the desired voltage range.

3) Connect the voltage being measured to the INPUT binding posts.

4) The value of voltage being measured will be indicated on one of two scales: 0-to-1 volt or 0-to-3 volts. When the range used contains the integer "1", the value of the voltage being measured will be indicated on the 1-volt scale; when the range used contains the integer "3", the value of the voltage will be indicated on the 3-volt scale. Each range switch position shows the maximum voltage that can be measured on the appropriate meter scale.

CAUTION

When making power line voltage measurements with this instrument you must be careful to avoid a serious short circuit. Connect only the red input terminal to the side of the power line that produces approximately the correct indication on the meter and then connect the black terminal to the other side of the line. By following this procedure you will avoid the short circuit that would result from connecting the black input terminal which is grounded to the ungrounded side of the power line.

b. Decibel Measurements -

Measurements in terms of decibels are made in the same way as voltage measurements except that the indication is read on the db scale (-12 to

+2 decibels). The level in decibels is the algebraic sum of the meter db-scale indication and the DB VOLTS (range) switch position.

1) To read power directly in dbm (0 dbm = 1 milliwatt into 600 ohms), the measurement must be made across 600 ohms.

2) Comparative db measurements (without respect to the reference level) may be obtained by direct reading provided each measurement is made across the same value of impedance. Made in this manner, the difference in decibels between two or more measurements may be obtained directly from the db-scale indications.

3) To obtain the level in dbm with respect to impedances other than 600 ohms, the meter correction graph shown in Figure 2-1 may be used. The level in dbm will be the algebraic sum of the level as indicated on the meter and the correction shown on the graph. For example, if the range switch is at the +30 db position, the measurement made across 90 ohms, and the indication on the DECIBELS scale +1, the level in dbm is obtained as follows:

+ 1 (db scale indication)
+30 (range switch position)
+31 (level in db as indicated by meter)
+ 8 (correction for 90 ohms impedance)
+39 dbm

For the same conditions, with the measurement made across 60,000 ohms:

+ 1 (db scale indication)
+30 (range switch position)
+31 (level in db as indicated by meter)
-20 (correction for 60,000 ohms impedance)
+11 dbm

EXAMPLES:

Range Switch	Meter Scale	Meter Indicates	Actual Level
<u>VOLTAGE MEASUREMENT</u>			
300	3	1.8	180
10	1	0.44	4.4
.003	3	2.3	.0023
.001	1	.27	.00027
<u>DB MEASUREMENT</u>			
+40 db	db	+2 db	+42 db
+40 db	db	-7 db	+33 db
+10 db	db	-6 db	+ 4 db
-30 db	db	0 db	-30 db
-30 db	db	-8 db	-38 db
* -50 db	db	-9 db	-59 db
-60 db	db	+1 db	-59 db
* NOTE: In case where a meter scale reading below - 8 db is obtained, it is best to switch to the next lower range on the instrument so a reading will be obtained in the upper portion of the scale where highest accuracy may be obtained.			

The same situation exists for voltage measurements. When a reading is obtained in the lower 1/3 scale, the range switch should be switched to the next lower range to obtain a reading in the upper 2/3 scale.

c. Amplifier -

The instrument may be used to amplify small signals. With full-scale meter deflection, the

amplifier open-circuit output is approximately .15 volt rms on all ranges. The response of the amplifier is flat across the band from 10 cycles to 4 mc. The impedance, looking into the OUTPUT terminals, is approximately 50 ohms over the entire frequency range. To obtain maximum gain, proceed as follows:

1) Turn the toggle switch to ON, and allow a warm-up period of approximately five minutes.

2) Set the DB VOLTS (range) switch at the .001-volt position.

3) Connect to the OUTPUT binding posts the equipment which is to receive the amplified signal. When the impedance of the load across the amplifier output is approximately 50 ohms, the output voltage will be approximately half the open-circuit voltage, or approximately .075 volt.

4) Connect the voltage to be amplified to the INPUT binding posts. Up to .002 volt may be applied to the amplifier with the range switch at the .001-volt position.

NOTE

Amplification also may be obtained on the .003, .01, .03, and .1 volt ranges, but maximum gain is available only on the .001 volt range because of the 10 db loss per step inserted by the DB VOLTS switch as the switch is turned in a clockwise direction.

SECTION III

THEORY OF OPERATION

3-1 GENERAL

The circuit of this voltmeter includes a two-step voltage divider in the input, a stabilized broadband amplifier, a rectifier and meter circuit, and a regulated power supply. Arrangement of the circuit is shown in block diagram form in Figure 3-1, and in detail on the schematic diagram.

The voltage under measurement is applied to the voltmeter at the input terminals. On the lower ranges the voltage is coupled directly to the grid of a cathode follower, the cathode of which is connected as a voltage divider tapped for six outputs. On the higher ranges the voltage is reduced to a thousandth of its value at INPUT before it is applied to the grid of the cathode follower. Out of the six-tap divider the voltage is coupled to a four-stage amplifier. The output of the amplifier feeds into a full-wave rectifier bridge with a dc milliammeter across its midpoints, and a current proportional to the input voltage flows through the meter movement. The meter is so calibrated that the resulting deflection indicates

the rms value of a sine-wave voltage applied at INPUT.

The circuit of the voltmeter is discussed in greater detail in the following paragraphs.

3-2 INPUT VOLTAGE DIVIDER

The input voltage divider consists of a 1000:1 resistive voltage divider feeding into the grid of tube V1, and a six step resistance voltage divider feeding into the first stage (V2) of the amplifier. The 6 step voltage divider is connected into the cathode circuit of V1, which is arranged as a cathode follower. Connections to both resistive dividers are set up by the DB VOLTS switch, by means of which the circuit may be arranged to operate on any one of twelve ranges.

a. 1000:1 Voltage Divider -

With the DB VOLTS (range) switch on any one of the six lower ranges (.001 volt to .3 volt), section

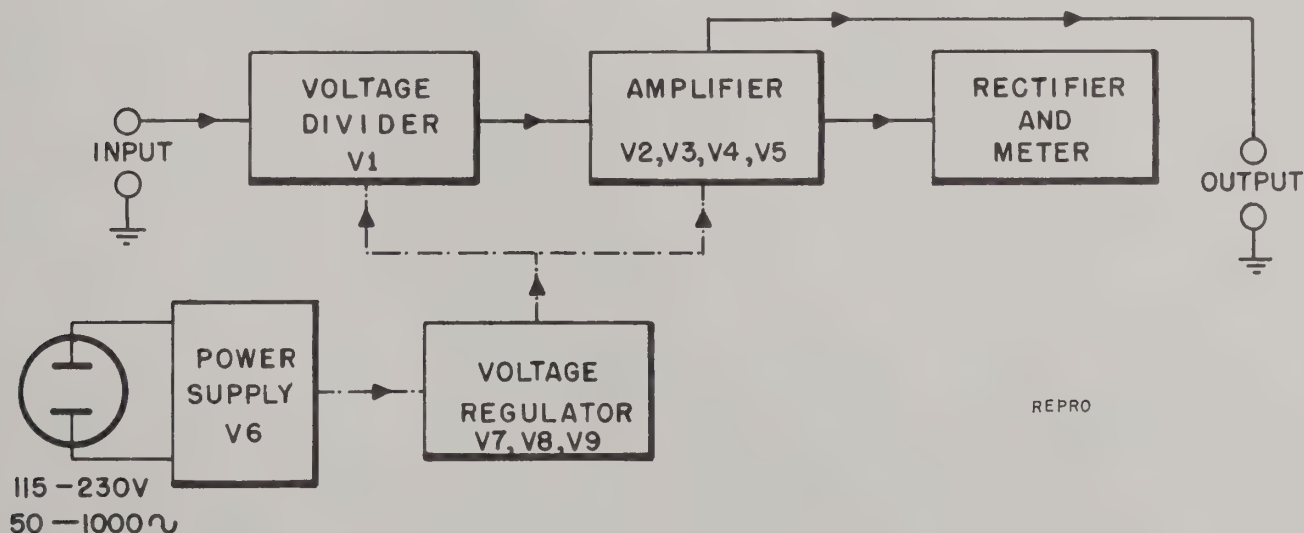


Figure 3-1. Model 400D/H/L Block Diagram

S1A of the range switch sets up connections in such a manner that the input voltage is applied directly to the grid of cathode follower V1 without being reduced by the 1000:1 divider. With the range switch on any one of the six higher positions (1 volt to 300 volts), section S1A establishes the connection between the grid of V1 and the resistive divider at the junction of resistors R3 and R4, and the input voltage is reduced a thousand-to-one before it is applied to the grid of V1.

b. Six-Step Voltage Divider -

Two series-connected wirewound resistance (R10A, B and R11A, B, C, D) in the cathode circuit of cathode follower V1 constitute a resistance divider tapped for six output voltages.

The six taps are brought out to contacts on section S1B of the DB VOLTS switch. The movable member of S1B is fashioned with two contacting arms, spaced at 180° . Thus as the switch is moved through the full range of its rotary travel, contact is made twice with each of the six taps, once on the travel through the six lower ranges and once on the travel through the six higher ranges. Since on the six higher ranges the input voltage is divided by a thousand before it is applied to the 6 step divider, each tap in the resistive divider serves two ranges, thus making available a total of twelve ranges.

The output from V1 is applied to the grid of V2, the first stage of the amplifier. For full scale deflection of the meter, the maximum voltage that can be applied to the grid of V2 is .001 volt. The resistance divider in the cathode circuit of V1 provides such reduction on each range that for full scale voltage at the INPUT terminals, the voltage applied to the grid of V2 will not exceed .001 volt.

The rc networks in the cathode circuit of V1 minimize dc switching transients while the ranges are being changed. The variable capacitors switched into the circuit on the .01/10 volt and .003/3 volt ranges are provided for adjustment of the high-frequency response. The trimmer capacitor connected across the 1000:1 divider compensates for stray capacity to keep the division ratio constant over the full frequency range.

3-3 AMPLIFIER, RECTIFIER AND METER

The four-stage amplifier provides high gain over a wide frequency range. The amplifier output is applied to a full-wave rectifier actuating a 1-milli-ampere meter movement. The amplifier-rectifier system is stabilized with an overall feedback loop. At the edges of the frequency range, the amount of negative feedback is controlled to provide the maximum stability consistent with the gain available.

a. Amplifier -

Between the grids of V2 and V5 the amplifier yields a net gain of approximately 55 to 60 db over a 10-cycle to 4-megacycle band. A high level of negative feedback, frequency compensating networks in the plate circuit of each stage, and cathode degeneration at low frequencies (the cathode resistors are not bypassed at low frequencies) provide an amplifier of high stability which can operate over an extremely wide (10-cycle to 4-mc) band. The feedback of the amplifier is returned from the plate of the last stage (V5), through the rectifier-meter circuit, to the cathode of first stage (V2) in such phase as to be degenerative in effect. The gain is adjusted by means of variable resistor R29 in the feedback loop. Another adjustment in the feedback loop, variable capacitor C21, is used for adjusting the frequency response of the amplifier at high frequencies.

The stages of the amplifier are resistance-capacitance coupled. The coupling circuitry between each stage is frequency-compensating, and provides separate coupling for low and high frequencies. This feature of the circuit design contributes to the stability of the amplifier across the wide band over which the voltmeter is rated to operate.

When the instrument is used as an amplifier, pentode V5 is operated as a cathode follower and supplies voltage at the OUTPUT terminals. The impedance, looking into the OUTPUT terminals, is approximately 50 ohms.

The output from the plate of V5 is delivered to a fullwave rectifier.

b. Rectifier and Meter -

The rectifier-meter circuit is arranged in a bridge-type configuration, with a crystal diode and a capacitor in each branch and a dc milliammeter connected across its midpoints. The diode connection provides fullwave rectification of the input current. The design of the bridge is such that 1) a pulsating direct current is delivered to the meter circuit and 2) an alternating current of the same frequency as the current at the rectifier input is delivered to the output of the bridge. From the rectifier-bridge output, the ac flows through the feedback loop to the cathode of V2.

The current through the meter is proportional to the average value of the waveform of the voltage applied to the input of the rectifier. Since calibration of the meter in rms volts is based on the ratio that exists between the average and effective values of a voltage that is a true sine wave, deviation in a waveform from that of a true sine wave may cause meter measurements to be in error. Table 2-1 gives an indication of the limits of possible error

due to the presence of harmonics in the waveform of a voltage under measurement.

NOTE

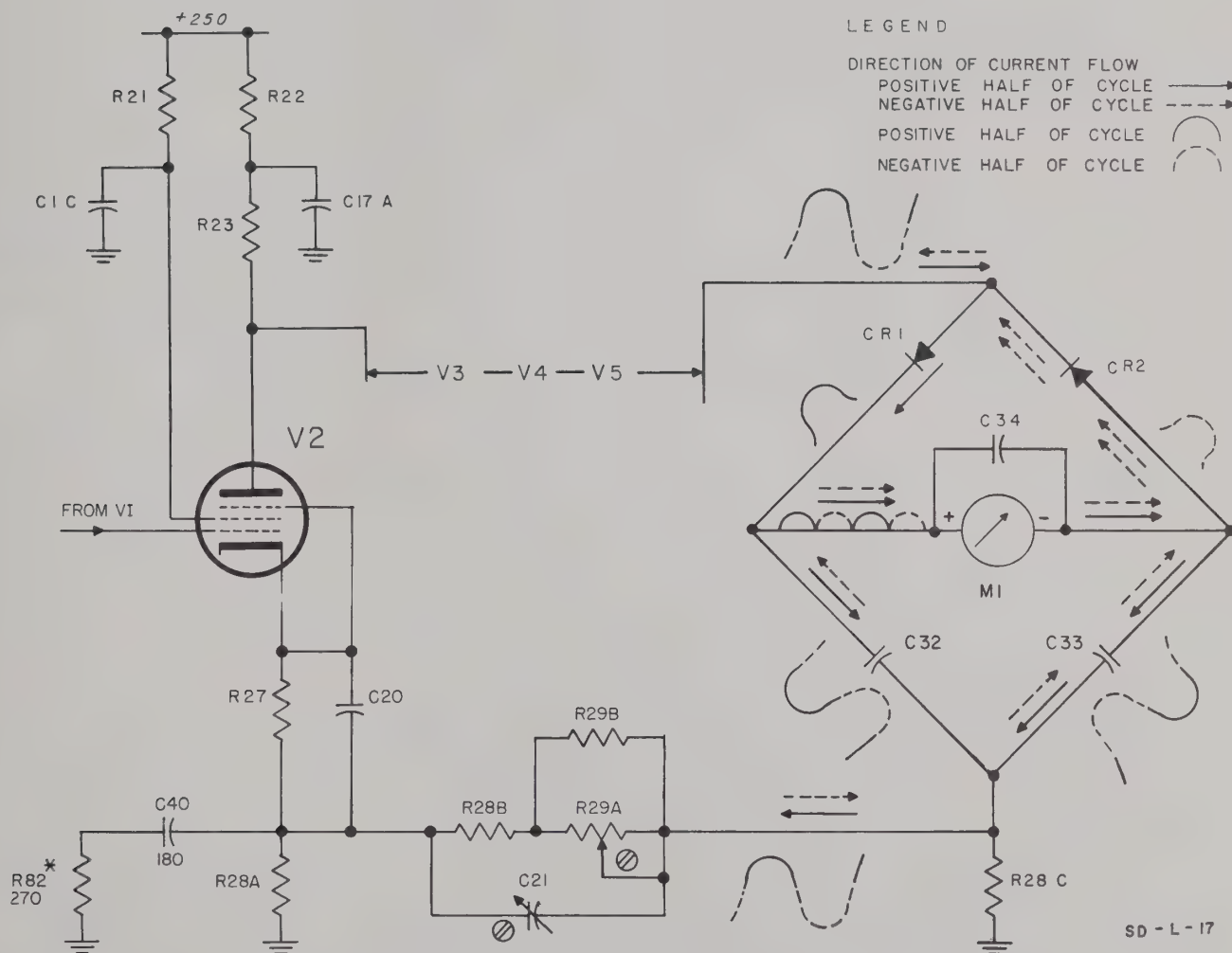
This table is universal in its application since these errors are inherent in all voltage measuring equipment of the average responding type.

The current flow through the rectifier-meter circuit is shown in Figure 3-2. For purposes of explanation, the amplifier (tubes V2-V5) may be considered as a signal generator with the output from the plate of V5 as one side, and the cathode of V2 as the other side. The rectifier-meter circuit may be considered as a bridge across the generator. On the positive half of the cycle, current flows into the bridge from

the top. On the negative half of the cycle, current flows into the bridge from the bottom.

On the positive half of the cycle, diode CR1 conducts, and current flows through CR1 to the juncture between the meter and capacitor C32, where it divides, a portion placing a charge on capacitor C32 and the rest flowing through the meter. Since diode CR2 is non-conducting, the current from the meter output flows to capacitor C33, placing a charge thereon. As capacitor C32 and C33 discharge, current flows to the generator.

On the negative half of the cycle, diode CR2 is biased to conduct, and diode CR1 is non-conducting. The current flowing into the bridge at the juncture between capacitors C32 and C33 divides, half placing a charge on C32 and the other half on C33. Since



diode CR1 is non-conducting, as capacitor C32 discharges, current flows through the meter and diode CR2 to the generator. As capacitor C33 discharges, current flows through CR2 to the generator. The action of capacitors C32 and C33 results in the flow of an alternating current in the feedback loop, so phased that it is negative in effect with respect to the signal on the grid of V2. Capacitor C34 across the meter integrates the ac component.

3-4 POWER SUPPLY

The power supply circuits provide a high-voltage regulated dc for the plate circuits of tubes V1 to V5 and a low-voltage unregulated dc for the filament circuits of tubes V1 to V4. The filament circuits of tubes V5 to V8 are supplied directly with 6.3-volt ac from windings in the secondary of power transformer T1.

a. Input Circuit -

The primary windings of power transformer T1 may be connected for operation from either a 115 volt

($\pm 10\%$) or a 230 volt ($\pm 10\%$) 50/1000 cps source. The primary circuit is fused. When switch S2 is in the ON position, power from the line is applied to the primary winding of transformer T1.

b. High-Voltage Supply -

Current for the high-voltage supply is rectified by V6, and regulated by triode V7. Amplified control voltage is supplied to grid of V7 by the pentode section of V8. The triode section of V8 acts as a dc cathode follower driving the pentode section.

Noise from reference tube V9 is eliminated by low-pass filter R63 and C35.

Dc drift due to changes in V8 filament voltage is canceled by differential action between the two sections of V8.

c. Filament Supply -

Current for the low-voltage dc filament supply is rectified by selenium rectifier SR1 and is filtered by capacitors C39A and C39B. Variable resistor R66 provides a means of adjusting the filament voltage.

SECTION IV MAINTENANCE

4-1 INTRODUCTORY

This section contains instructions for maintaining and trouble shooting the instrument. A tube replacement chart lists the checks and adjustments required after tube replacement, and a trouble-shooting chart assists in localizing most troubles which might occur. Photographs showing the physical location of components, a voltage and resistance diagram, and a schematic diagram are also provided for your convenience.

The more intricate adjustment procedures described in this section are provided for those who have the necessary test equipment. When qualified personnel and test facilities are not available, it is suggested that adjustments not be made in the field. Instructions are given on the Warranty page in this manual for the procedure to be followed should repair service be required.

The following information appears in this section:

- 4-2 Meter Zero Adjustment
- 4-3 Case Removal
- 4-4 Tube and Crystal Diode Replacement
- 4-5 Required Test Equipment
- 4-6 Rapid Performance Check
- 4-7 Complete Adjustment and Test Procedure
- 4-8 Trouble Shooting
- 4-9 Power Supply Trouble Localization
- 4-10 Amplifier Trouble Localization

4-2 METER ZERO ADJUSTMENT

The most accurate positioning of the meter pointer will result if the vtvm is allowed to warm-up for at least 15 minutes with the cabinet in place.

A. MODELS 400D AND 400H

Turn warmed-up instrument off and allow about two minutes for internal capacitors to discharge.

Rotate the meter mechanical zero adjusting screw clockwise until the meter pointer is traveling down-scale toward zero and stop at zero. If you over-

shoot, continue rotating the adjustment screw clockwise and again approach zero from the high side of the scale. The adjustment screw should not be turned counterclockwise during any part of this procedure.

B. MODEL 400L

The special meter in the 400L is adjusted with the vtvm turned ON since the meter pointer rests against the stop at the left end of the scale when the instrument is turned OFF. The mechanical zero is preset during manufacture of the meter movement.



4-3 CASE REMOVAL

The instrument case (or dust cover) is fastened to the rear of the chassis with two screws. To remove the case, remove the screws, and slide the case to the rear and off the instrument.

4-4 TUBE & CRYSTAL DIODE REPLACEMENT

Tubes with standard EIA characteristics can be used for replacement. In a great number of cases, instrument trouble can be traced to a defective or weak tube. Replace only those tubes proven to be defective or weak. Check tubes by substitution. Results obtained through the use of a "tube checker" can be erroneous and misleading. Mark original tubes to insure that they are returned to the same socket if not replaced.

The power supply should be checked after replacing V6, V7, V8, or V9 in the power supply.

Heater voltage must be checked and adjusted after replacing V1, V2, V3, or V4. Factory selected tubes are available for V1 and V2. These tubes are tested for low noise and microphonics. Contact your  Sales Engineering Representative for the  Stock Numbers and prices on these tubes.

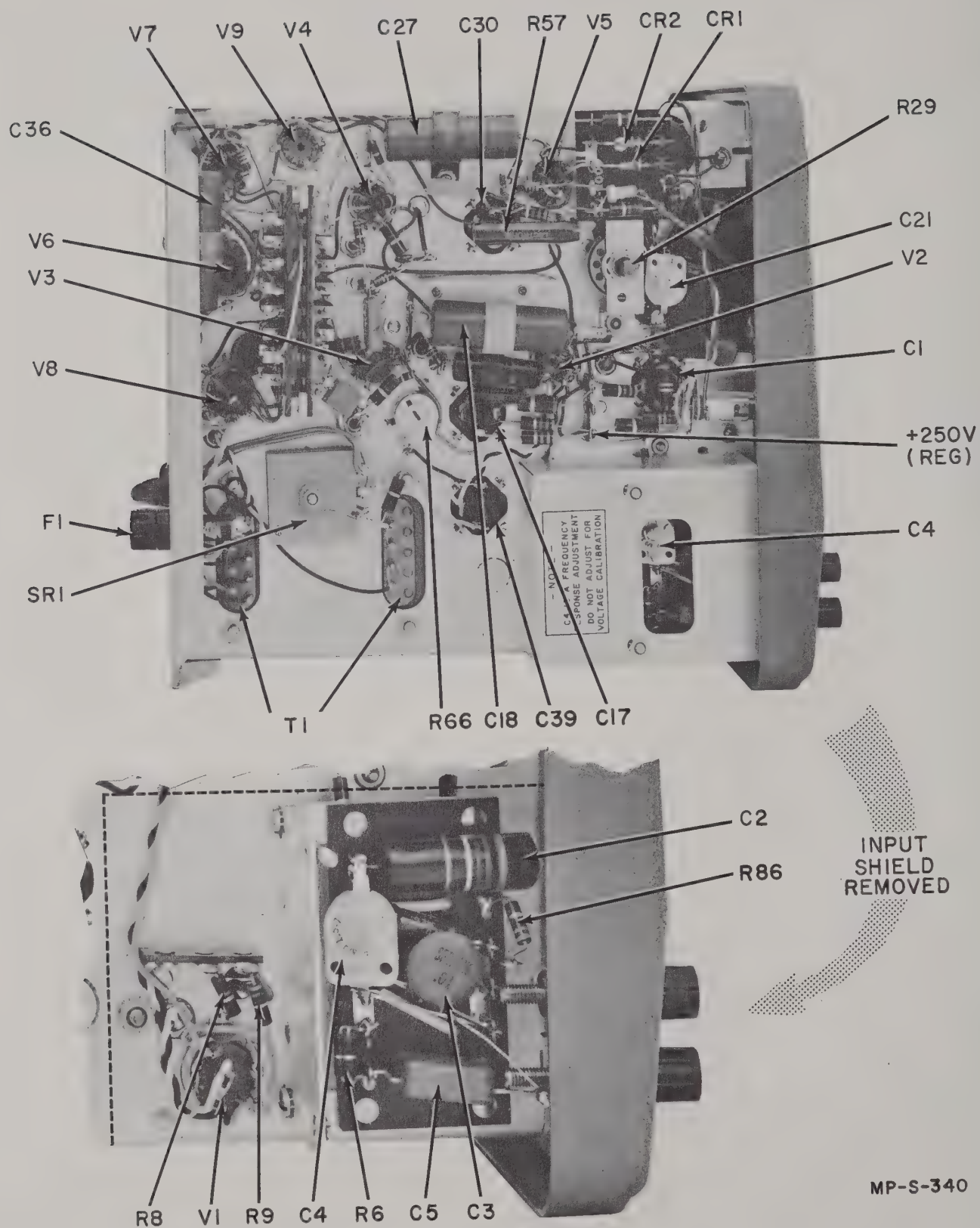


Figure 4-1. Model 400D/H/L View of Left Side Instrument Case removed

TABLE 4-1. TUBE REPLACEMENT

Tube	Function	Circuit Adjustment
V1 - 6CB6	Cathode Follower	DC Heater Voltage, paragraph 4-7C
V2 - 6CB6	1st Amplifier	Rapid Performance Check, paragraph 4-6
V3 - 6CB6	2nd Amplifier	
V4 - 6CB6	3rd Amplifier	
V5 - 6CB6	4th Amplifier	
V6 - 6AX5	High Voltage Rectifier	Regulated power supply, paragraph 4-7B
V7 - 12B4A	Power Supply Series Regulator	
V8 - 6U8	Power Supply Control Tube	
V9 - 5651	Reference Tube	

Special high-performance junction type silicon diodes are used for CR1 and CR2. These special diodes are manufactured by hp and are available directly from the factory or from your hp Representative. The cathode end of the diodes has a gold plated wire and is also color coded green. The anode end has a silver plated wire.

These diodes have a junction that is less than 1/2 mil in diameter and, if dropped, a mechanical failure may occur at the junction. After installation the diodes will withstand any shock that the entire instrument can withstand.

Voltage calibration and frequency response should be checked and adjusted after replacing V1, V2, V3, V4, V5, CR1, or CR2.

4-5 REQUIRED TEST EQUIPMENT

The following equipment is required to test and calibrate hp Vacuum Tube Voltmeter Models 400D, 400H, and 400L.

1) A dc voltmeter capable of measuring 250, 6.3, 12.6 volts. This voltmeter must have a sensitivity of 1000 ohms/volt or better. A vtm such as the hp Model 410B is satisfactory.

2) An hp Spec. 23678 Voltmeter Calibration Generator or equivalent. The Spec. 23678 generator will deliver a 400 cps output voltage from 0.3 millivolt rms to 300 volts rms with an accuracy of $\pm 0.25\%$ and

not more than 0.2% hum and distortion. This generator will also supply +dc or -dc voltages from 0.3 millivolt to 300 volts for calibration of dc voltmeters.

3) An hp Spec. 23679 VTVM Frequency Response Generator. This generator has an internal signal source to cover the frequency range from 350 kc to 11 mc. Up to a 3 volt output signal can also be obtained. The internal attenuator and reference voltmeter are designed for frequencies from 10 cps to 11 mc. Internal impedance is 50 ohms.

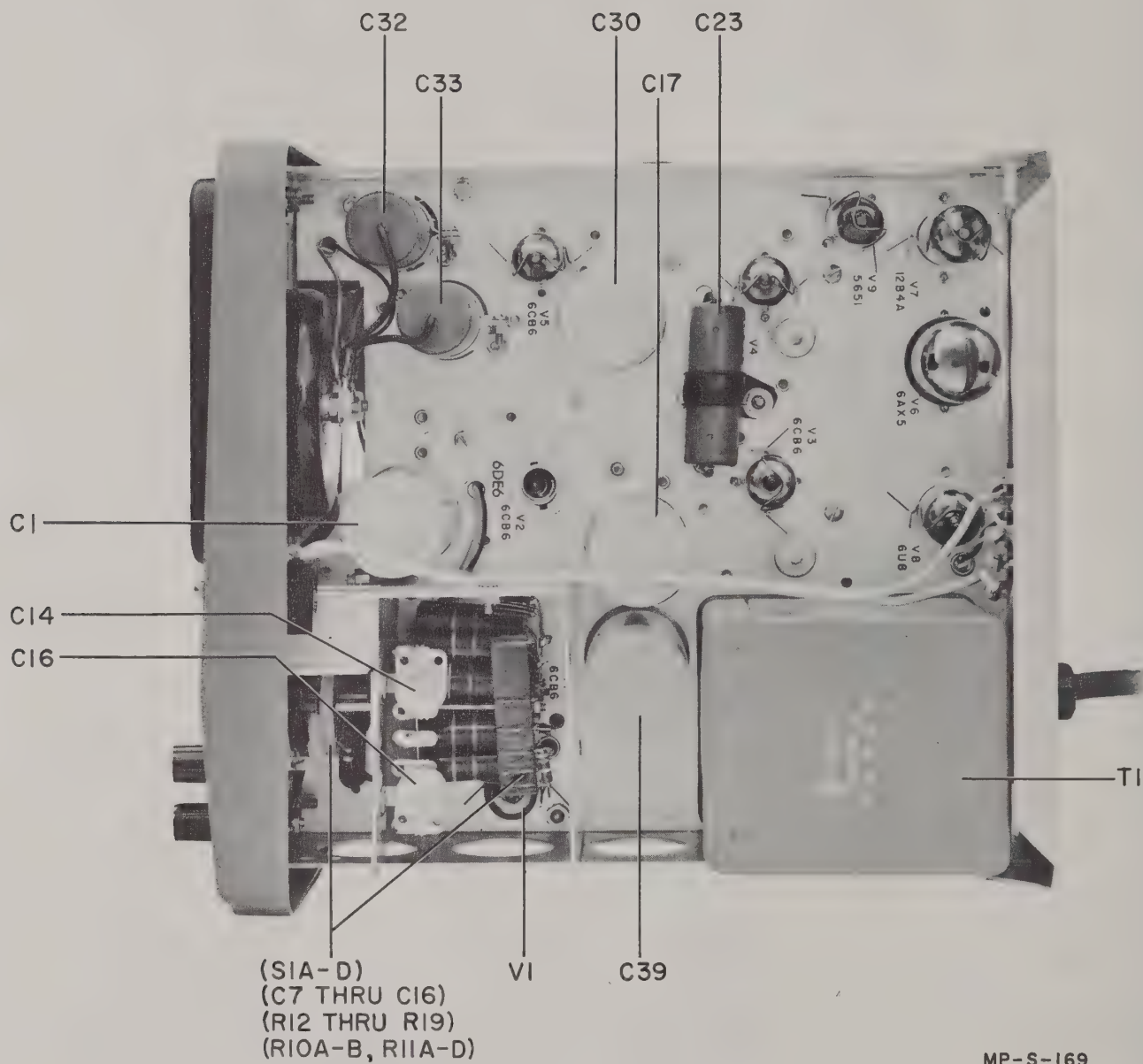
4) An hp Spec. 23680 Wide Range Oscillator. This oscillator has an internal impedance of 50 ohms and will deliver a 3 volt signal from 5 cps to 600 kc. Use with Spec. 23679 VTVM Frequency Response Generator.

5) A square wave generator capable of delivering a 2 volt peak-to-peak 1 kc signal. The hp Model 211A Square Wave Generator or the internal calibrator in the hp Model 150A High Frequency Oscilloscope can be used.

6) A high frequency oscilloscope such as the hp Model 150A.

7) An adjustable line voltage source with meter accurate to within 1 volt.

The hp Spec. 23679 VTVM Frequency Response Generator and the hp Spec. 23680 Wide Range Oscillator are designed to be operated together when making frequency response measurements. These two instruments greatly increase the speed and accuracy of frequency response measurement.



MP-S-169

Figure 4-2. Model 400D/H/L View of Right Side Instrument Case Removed

The procedure in this manual contains an "alternate method" for frequency response adjustments. This "alternate method" is based upon using the alternate instruments in the following list in place of the Spec. 23679 and Spec. 23680 instruments.

---A low distortion oscillator covering the frequency range from 10 cps to at least 6.4 mc and an output voltage of at least 3.0 volts rms. The Φ Model 650A Test Oscillator will meet these requirements.

---An rms reading, average responding, ac voltmeter with a known frequency response from 10 cps to 6.4 mc. The reference voltmeter can be an Φ Model 400H or Model 400L. A thermocouple type of reference meter can also be used. Absolute voltage values are not needed when making frequency response measurements.

4-6 RAPID PERFORMANCE CHECK

The following tests may be used to check the operation of the instrument without going through the complete test procedure. An instrument that passes these tests will generally meet all specifications, but this CANNOT be considered as a complete certification procedure.

The following equipment is needed for the Rapid Performance Check. See paragraph 4-5 for a detailed description of these instruments.

---An adjustable line voltage source with meter.

---Voltmeter Calibration Generator.

---Source of a 10 cps sine wave signal with an amplitude of at least 1.0 volt.

All measurements should be made with line voltage set to 115 volts unless otherwise specified.

A. MODELS 400D or 400H ONLY

If the instrument being checked is a Model 400L, skip to steps B and C.

1) Warm-up vtm for at least 15 minutes and adjust meter zero as described in paragraph 4-2.

2) Set the vtm to the 0.3 VOLT range. Connect 0.3 volt from calibration generator to vtm INPUT. Adjust R29 so meter indication is 0.3 volt. Check full scale calibration accuracy on all ranges: $\pm 2\%$ for 400D and $\pm 1\%$ for 400H.

B. MODEL 400L ONLY

If the instrument being checked is a Model 400D/H, complete step A and skip to step C.

1) Allow the instrument to heat for at least 15 minutes. Set to the .3 volt range and apply .3 volt from the calibration generator, adjust R29 if necessary to obtain a .3 volt indication on the meter.

2) Check the full scale calibration of the remaining ranges. They should all fall within $\pm 1\%$.

3) Set the 400L to the 1 volt range and feed in 1 volt. Check full scale. Drop the input voltage to 0.3 volt. The meter should track within 1% of the reading. Failure to track properly may be due to defective diodes, a defective V5 or possibly the return spring adjustment in the meter movement has shifted. The return spring adjustment is made by the meter manufacturer and cannot be made without removing the meter movement from its case. It is not recommended that this adjustment be made because of the chance that dust or metal particles may get into the moving coil system which will completely disable the movement. The spring setting also affects the full scale setting. The meter amplifier gain must be reset with R29 each time the spring is moved until a setting is found which gives good tracking over the whole scale.

C. MODEL 400D, 400H, and 400L

The following measurements should be completed after either step A or step B.

1) Set line voltage to 115 volts.

2) Set the range switch to the 1 volt range and apply a 1 volt 10 cycle sine wave to the INPUT. The absolute input voltage is not important here, you are merely establishing a reference indication of 1 volt.

3) Reduce the line voltage input to the instrument to 103 volts and watch the meter indication. The meter indication should not change more than 5% from the reference established in step 2 after the instrument has been operating on reduced line voltage for a period of several minutes.

Successful completion of these steps indicates that the instrument will probably meet all specifications. If it will not, it will be necessary to resort to the complete test procedure in paragraph 4-7.

4-7 COMPLETE ADJUSTMENT AND TEST PROCEDURE

Usually a particular voltmeter will not need complete testing and calibration. Only one or two tests will be needed and they can be done without completing the entire test procedure. For example, basic calibration can be checked and adjusted at any time without making any other adjustments.

The following procedures are listed in a recommended sequence for a complete test and calibration operation. In general, tubes are the main cause of trouble and new ones should always be tried before making adjustments or other component replacements. See paragraph 4-4 before changing tubes.

The specifications for your ϕ Model 400D, 400H, or 400L Vacuum Tube Voltmeter are given in the front of this manual. The following test procedure contains extra checks to help you analyze a particular instrument. These extra checks and the data they contain can not be considered as specifications.

A ten to fifteen minute warm-up and power supply output voltage measurements are always recommended before making any other test or adjustment.

NOTE

The test frequencies and the voltages specified in many of the steps in this procedure are based upon the use of the test equipment listed in paragraph 4-5. Other frequencies and voltages can be used. Any vtvm can be adjusted for optimum performance on the range you most commonly use.

A. METER ZERO ADJUST

If a Model 400D or 400H vtvm is involved, follow the zero adjustment procedure in paragraph 4-2.

The mechanical zero for the special meter in the Model 400L vtvm is preset during manufacture of the meter movement.

B. CHECK REGULATED POWER SUPPLY

1) The B₊ voltage at the output of the regulated power supply should be 250 volts, ± 5 volts. Measure this voltage between the chassis and the cathode of the series regulator tube with the line voltage set to 115 volts.

2) Vary the line voltage between 103 and 127 volts. The regulated B₊ will usually change no more than 2 volts from one extreme to the other. Ripple voltage in the regulated B₊ is usually 3 millivolts or less under these same test conditions.

The dc voltage at the plate of the series regulator tube or at the cathode of the rectifier tube should be between 400 and 420 volts with a 115 volt line. Low voltage at this point may be from a defective rectifier tube, filter capacitor, or power transformer.

To check the rectifier tube, connect a dc voltmeter between chassis and the rectifier cathode. Reduce line voltage from 115 to 103 volts. The voltmeter reading should drop as line voltage is reduced and then remain steady. If the dc voltage continues to drop at a slow rate, the rectifier tube is probably weak and should be replaced.

If the regulated B₊ voltage is not correct, replacement of any or all four tubes in the power supply may be necessary. If tube replacement does not correct the dc voltage, precision resistors R62 and/or R64 may have changed value and should be replaced. Abnormal current drain caused by component failure elsewhere in the vtvm can result in poor power supply regulation.

Excessive ac ripple may be from a defective tube in the power supply other than the rectifier tube. Capacitor C36 may be open.

C. SET DC HEATER VOLTAGE

1) Adjust control R66 to set the dc heater voltage for tubes V1 and V2 to 6.3 volts ± 0.2 volt. The dc voltages across the heaters of tubes V3 and V4 must also be 6.3 volts ± 0.2 volt. DO NOT USE A VOLTMETER THAT IS CONNECTED TO A COMMON GROUND WITH THE VTVM UNDER TEST WHEN MEASURING THESE HEATER VOLTAGES - A SHORT CIRCUIT WILL RESULT. Slight readjustment of control R66 will often bring these two voltages within tolerance.

2) If both voltages cannot be set to 6.3 volts, ± 0.2 volt, adjust R66 to bring the lowest of the two voltages within tolerance. Connect a resistor in parallel with the two heaters with the highest voltage. The correct resistor value will enable you to bring both heater voltages within tolerance by readjusting control R66. Use only one resistor in parallel with one pair of tubes at a time. A resistor value below 220 ohms, 1 watt, should not be used.

3) If you are unable to obtain the correct heater voltage after completing steps 1 and 2, check electrolytic capacitors in the heater circuit. If both heater voltages are low, check selenium rectifier SR1.

D. INPUT CIRCUIT PRELIMINARY FREQUENCY RESPONSE ADJUSTMENT

1) Connect a 1 kc, 2 volt peak-to-peak, square wave signal to the INPUT of the vtvm under test. Connect the OUTPUT terminals of the same vtvm to the vertical input of a high frequency oscilloscope such as the ϕ Model 150A.

2) Switch the vtvm to the 1.0 volt range and adjust capacitor C4 for the best square wave pattern on the oscilloscope.

E. BASIC CALIBRATION (SETTING AMPLIFIER GAIN)

Connect a 0.3 volts rms, 400 cps signal from the Calibration Generator to the vtvm INPUT. Switch the vtvm to the 0.3 volt range and adjust the feedback control (R29) to obtain a reading of 0.30 volts.

F. BASIC CALIBRATION (SETTING INPUT DIVIDER)

1) Connect a 1.0 volt rms, 400 cps, signal from the Voltmeter Calibration Generator to the INPUT of the vtvm under test. Switch the vtvm to the 1.0 volt range.

2) The voltmeter indication will normally be 1.0 volts. If the reading is high, decrease the value of the pad in parallel with R3. If the reading is low, increase the value of the pad. Resistor R3 and pad are on the input circuit board.

G. RECHECK DC HEATER VOLTAGE

Check the dc heater voltage by the method given in paragraph 4-7C.

If either electrolytic capacitor in the heater circuit has been replaced, a heat-run of several hours should be allowed. After the heat-run to form the capacitor plates, reset the heater voltage.

H. CHECK CALIBRATION & TRACKING

1) Check full scale accuracy of each voltmeter range. Use the Voltmeter Calibration Generator. The calibration should be within $\pm 2\%$ of full scale for a 400D voltmeter or $\pm 1\%$ of full scale for a 400H or 400L voltmeter. The test voltage should be between 50 cps and 500 kc. Avoid using the power line frequency or a harmonic of the power line frequency. Refer to the accuracy specifications if you use a test frequency outside of this range.

2) Check meter tracking on any mid-range. The 1 volt range is usually convenient. A sticky meter can cause the vtvm to be outside of the calibration specifications. Defective diodes for CR1 and CR2 can also introduce excessive tracking error. Refer to paragraph 4-4 for information on replacement diodes.

I. CHECK EFFECT OF LINE VOLTAGE CHANGE

1) Connect a sine wave signal to the INPUT of the vtvm under test. Use a convenient mid-range and adjust the input signal amplitude for a convenient

reference level such as 0.9. Use any frequency within the frequency range of the voltmeter. The line voltage should be at 115 volts for at least two minutes before setting your reference level.

2) When the line voltage is changed from 115 to 103 or from 115 to 127 volts, the indication on the vtvm under test will normally not change from the reference level by more than $\pm 2\%$ of full scale after a two minute period.

These effects are more noticeable at the upper and lower limits of the vtvm frequency range. If the change is excessive, check tubes V5 through V1 in that order.

J. FREQUENCY RESPONSE ADJUSTMENT WITH SPEC. 23679 & SPEC. 23680 INSTRUMENTS

The following frequency response adjustment procedure is based upon the use of the Φ Spec. 23679 VTVM Frequency Response Generator and the Φ Spec. 23680 Wide Range Oscillator.

The input voltage to the vtvm under test is essentially monitored by the reference meter in the Frequency Response Generator. The indication on this monitor meter at 400 cps will be called "SET LEVEL" in the steps that follow.

Follow the procedure in paragraph 4-7K if the Spec. 23679 and Spec. 23680 equipment is not available.

NOTE

The frequency response of the instrument will probably not need adjustment. These steps have been included to verify the instrument response and to restore proper operation in case the original adjustment is altered. Failure to meet any of the following tests can usually be traced to one or more weak tubes.

1) Connect a 400 cps sine wave signal to the INPUT of the vtvm under test. Adjust signal level for a reading of 0.90 on the .001 volt range. Adjust monitor meter to "SET LEVEL".

2) Change input signal to 4 mc and set amplitude to "SET LEVEL". Adjust capacitor C21 in the vtvm under test for a reading of 0.90.

3) Change input signal to 1 mc and set amplitude to "SET LEVEL". Capacitor C26 in the plate circuit of V4 can be adjusted in value between limits of 15 $\mu\mu\text{f}$ and 82 $\mu\mu\text{f}$ to control 1 mc response. If you change C26, repeat steps 1 through 3.

4) Change input signal to 6.4 mc and set amplitude to "SET LEVEL".

5) The reading on the vtm under test should not be more than 5% of full scale above 0.90. Any reading below 0.90 is acceptable. A high frequency peak is undesirable at frequencies above 4 mc.

If the reading is more than 5% high, add capacitor C40 and resistor R82 if not already in the cathode circuit of V2 in your vtm. Repeat steps 1 through 5 if these parts are added.

The values of R82 and C40 can be adjusted to bring the 6.4 mc response below the 5% maximum. If you change either R82 or C40 in value, repeat steps 1 through 5.

6) Change the input signal to 10 cps and set the amplitude to "SET LEVEL" step 1. The reading on the vtm under test should be 0.90, $\pm 5\%$ of full scale.

To increase the 10 cps indication, remove R80 if present in V2 grid circuit. Add R81 in V3 grid circuit if additional increase is needed after R80 removal. Conversely, to decrease the indication, remove R81 and add R80 if necessary. Either but not both resistors can be added. Both resistors can be omitted. A value of 2.2 megohms or higher should be used for R80 or R81 when adjusting low frequency response. Check tubes and coupling capacitors if you find that a resistor value below 2.2 megohms is required.

7) Increase the input signal to about 20 cps and set the amplitude to "SET LEVEL" of step 1. The reading on the vtm under test should not be more than $\pm 2\%$ of full scale from 0.90. If necessary, make compromise resistor adjustments to satisfy steps 6 and 7.

8) Switch the vtm under test to the 0.003 volt range. Establish a new 400 cps "SET LEVEL" with a reading of 0.90 on the 0 to 1 scale of the vtm under test.

9) Change the input signal to 4 mc and set the input amplitude to the "SET LEVEL" established in step 8. Set the reading on the vtm under test to 0.90 by adjusting capacitor C14.

10) Switch the vtm under test to the 0.01 volt range. Establish a new 400 cps "SET LEVEL" with a reading of 0.90 on the 0 to 1 scale of the vtm under test.

11) Change the input signal to 4 mc and set the input amplitude to the "SET LEVEL" established in step 10. Set the reading on the vtm under test to 0.90 by adjusting capacitor C16.

12) Check frequency response on the 0.03, 0.1, and 0.3 volt ranges. Establish a 400 cps "SET LEVEL" for each range and then check the response at 4 mc. If an error greater than $\pm 5\%$ of full scale is noted, make a compromise adjustment of C21. If the setting of C21 is changed, repeat all previous steps except 6 and 7. The compromise setting of C21 must be used when repeating step 3.

13) Switch the vtm under test to the 1.0 volt range. Establish a new 400 cps "SET LEVEL" with a reading of 0.90 on the 0 to 1 scale of the vtm under test.

14) Change the input signal to 20 kc and set the input amplitude to the "SET LEVEL" established in step 13. Adjust capacitor C4 for a reading of 0.90.

15) Change the input signal to 4 mc and set the amplitude to the "SET LEVEL" established in step 13. The reading on the vtm under test should not be more than $\pm 2\%$ of full scale from 0.90.

Adjust R6 in the input divider to bring the 4 mc response within $\pm 2\%$. This resistor consists of several parallel resistors. Increasing the resistance of R6 will raise the frequency response at 4 mc. Lowering the resistance will decrease the 4 mc response.

16) The frequency response of the 3 volt range can be checked. If other ranges have been properly adjusted this range will be within specifications.

K. FREQUENCY RESPONSE ADJUSTMENT WITH ALTERNATE EQUIPMENT

The following frequency response adjustment procedure is based upon the use of the alternate test equipment as explained in paragraph 4-5. In the following procedure, test frequencies of 10 cps, 1 mc, 4 mc, and 6.4 mc are given. The 10 cps and 4 mc frequencies are the band limits of the voltmeter. The 6.4 mc check point is for determining high frequency performance.

The input voltage to the vtm under test must always be monitored by a reference voltmeter having a known frequency response. The reference voltmeter reading at 400 cps will be called "reference level" in all steps that follow.

NOTE

The frequency response controls in the instrument will probably not need adjustment. These steps have been included to verify the instrument response and to restore proper operation in case the original adjustment is altered. Failure to meet any of the following tests can usually be traced to one or more weak tubes.

1) Connect a 400 cps sine wave signal to the INPUT of the vtvm under test. Adjust signal level for a reading of 0.90 on the 0.1 volt range: Adjust monitor meter to establish a "reference level" on the upper end of a convenient range.

2) Change input signal to 4 mc and set amplitude to "reference level". Adjust capacitor C21 in vtvm under test for a reading of 0.90.

3) Change input signal to 1 mc and set amplitude to "reference level". Capacitor C26 in the plate circuit of V4 can be adjusted in value between limits of 15 μf and 82 μf to control the 1 mc response. If you change C26, repeat steps 1 through 3.

4) Change input signal to 6.4 mc and set amplitude to "reference level".

5) The reading on the vtvm under test should not be more than 5% of full scale above 0.90. Any reading below 0.90 is acceptable. A high frequency peak is undesirable at frequencies above 4 mc.

If the reading is more than 5% high, add capacitor C40 and resistor R82 if not already in the cathode circuit of V2 in your vtvm. Repeat steps 1 through 5 if these parts are added.

The values of R82 and C40 can be adjusted to bring the 6.4 mc response below the 5% maximum. If you change either R82 or C40 in value, repeat steps 1 through 5.

6) Change the input signal to 10 cps and set the amplitude to the "reference level" of step 1. The reading on the vtvm under test should be 0.90, $\pm 5\%$ of full scale.

To increase the 10 cps indication, remove R80 if present in V2 grid circuit. Add R81 in V3 grid circuit if additional increase is needed after R80 removal. Conversely, to decrease the indication, remove R81 and add R80 if necessary. Either but not both resistors can be added. Both resistors can be omitted. A value of 2.2 megohms or higher should be used for R80 or R81 when adjusting low frequency response. Check tubes and coupling capacitors if you find that a resistor value below 2.2 megohms is required.

7) Increase the input signal to about 20 cps and set the amplitude to the "reference level" of step 1. The reading on the vtvm under test should not be more than $\pm 2\%$ of full scale from 0.90. If necessary, make compromise resistor adjustments to satisfy steps 6 and 7.

8) Switch the vtvm under test to the 0.01 volt range. Establish a new 400 cps "reference level" for this range by setting to 0.90 on the 0 to 1 scale.

9) Change the input signal to 4 mc and set the input amplitude to the "reference level" established in step 8. The reading on the vtvm under test should be set to 0.90 by adjusting capacitor C16.

10) Switch the vtvm under test to the 1.0 volt range. Establish a new 400 cps "reference level" by setting to 0.90 on the 1 volt range.

11) Change the input signal to 20 kc and set the amplitude to the "reference level" established in step 10. Adjust capacitor C4 for a reading of 0.90.

12) Change the input signal to 4 mc and set the amplitude to the "reference level" established in step 10. The reading on the vtvm under test should not be more than $\pm 2\%$ of full scale from 0.90.

Adjust R6 in the input divider to bring the 4 mc response within $\pm 2\%$. This resistor consists of several parallel resistors. Increasing the resistance of R6 will raise the frequency response at 4 mc. Lowering the resistance will decrease the 4 mc response.

13) Switch the vtvm under test to the 3.0 volt range. Establish a new 400 cps "reference level" by setting to 0.90 on the 0 - 1 scale.

14) Change the input signal to 4 mc and set the amplitude to the "reference level" established in step 13. Adjust capacitor C14 to obtain an indication of 0.90 on the vtvm under test.

L. FINAL CHECK & ADJUSTMENT

Repeat the Basic Calibration procedures given in paragraphs 4-7E and 4-7F.

4-8 TROUBLE SHOOTING

To assist in trouble shooting, a chart has been prepared which lists various trouble symptoms, possible causes and/or remedies. If the cause of trouble is of a more obscure nature than can be covered by the chart, trouble can be located by test: first by sectionalizing, and second by localization within the section by means of voltage and resistance measurements. The circuit sections are indicated in the block diagram (Figure 3-1).

1) The first step in sectionalizing is to check the output of the regulated high-voltage supply: the dc voltage between pin 1 of V7 and ground should measure 250 volts, ± 5 volts.

If the regulator output is not within these limits, see paragraph 4-9.

If the regulator output is within these limits, the power supply probably is functioning properly, and the remainder of the circuit should be tested.

Apply a signal at INPUT, and check the level of the signal voltage at the input and output of each of the sections shown in Figure 4-3, except the levels at 1st amplifier V2. (The low level of signal applied to the grid of V2, together with the large amount of negative feedback applied to its cathode, make any signal-voltage measurements at V2 impractical.) Typical signal voltages at the input and output of each section, for an input signal of 0.3 volt at 400 cycles, may be found in Figure 4-3, a servicing block diagram.

2) When trouble has been localized to a particular section, it is recommended that tube substitution be tried before any other tests are made. If tubes known to be good do not clear the trouble, voltage-resistance measurements should be made. Typical voltage and resistance values may be found on Tube Socket Voltage-Resistance Diagram, Figure 4-4.

For the circuitry in each section reference may be made on the schematic diagram. The servicing block diagram (Figure 4-3) shows the signal path in heavy line and directional arrows. Feedback paths are shown by means of directional arrows, but in lighter line.

Localization by dc voltage analysis is discussed in paragraph 4-10.

TABLE 4-2. TROUBLE SHOOTING CHART

Symptom	Possible Cause and/or Remedy
Instrument dead, indicator lamp does not light.	<p>Fuse blown - replace. If fuse blows again, check for a short circuit or defective tube or component in power supply and/or heater circuits.</p> <p>Off-on switch defective.</p> <p>Line cord defective.</p>
Instrument dead, indicator lamp glows, meter does not indicate.	<p>No output from regulated power supply. Refer to paragraph 4-9.</p> <p>Tubes V1, V2, V3, V4 and/or V5 defective.</p> <p>Defective component in amplifier.</p> <p>Defective CR1 and/or CR2 diode, C34 capacitor, or meter movement. Check instrument calibration after repair.</p>
Residual meter reading erratic and higher than 2-1/2 divisions on the .001-volt scale. (Input must be well shielded.)	<p>This is usually accompanied by erratic meter indications. See Meter Indication Erratic.</p>
Residual meter reading steady and higher than 2-1/2 divisions on the 1-volt scale.	<p>Trouble in power supply (see paragraph 4-9).</p> <p>V1, V2, V3, V4, and/or V5 defective.</p> <p>Defective component in amplifier.</p> <p>Noisy R23.</p> <p>Check mechanical zero.</p> <p>Capacitor C6 is formed by wires connecting to adjacent tie lug terminals. If the heater leads for V1 are dressed so that they pass between these terminals, hum is introduced.</p>

TABLE 4-2. TROUBLE SHOOTING CHART (CONT'D)

Symptom	Possible Cause and/or Remedy
Meter indication is equally erratic on all ranges.	Trouble in power supply (see paragraph 4-9). Tubes V2, V3, V4 and/or V5 defective. Crystal diode CR1 and/or CR2 defective. Capacitor C2 may be shorted or leaky. Noisy R23.
Meter indication more on one range than on other ranges.	Leaky 0.051 μ f coupling capacitor in range switch. Replace defective unit.
Meter pointer "beats" when power line frequency (usually 60 cps) or a harmonic thereof is applied to INPUT.	Trouble in power supply (see paragraph 4-9). Heater-cathode leakage in V1, V2, V3, V4 or V5. Replace one tube at a time. Readjust heater dc voltage after final tube selections have been made. Recalibrate instrument (paragraph 4-7). Open bypass or decoupling capacitor anywhere in instrument.
Repeated adjustment to increase amplifier gain needed to maintain calibration.	Trouble in power supply (see paragraph 4-9). Tubes V1, V2, V3, V4 and/or V5 defective. Crystal diodes CR1 and/or CR2 defective. Capacitors C32, C33, and/or C34 defective.
Meter pointer strikes peg sharply when switching ranges, particularly when switching from 0.3- to 1-volt range with no input.	Tubes V1, V2, and/or V5 are the most probable tube defects. However, V3 and/or V4 may be defective.
Delayed secondary switching transient particularly when switching from the 0.3- to the 1-volt range with no input.	The only disadvantage of this is a slight increase of instrument recovery time when switching ranges. Most probably caused by a gassy tube for V1, V2, and/or V5. May also be V3 and/or V4. A similar symptom may exist between any two ranges when any of C7 through C12 capacitors are leaky.
Microphonics (Mechanical shock causes excessive fluctuation of voltmeter reading.)	With DB VOLTS switch on 1-volt range, apply a 1-volt (400 to 1000 cps) signal to INPUT. Lightly tap lower right corner of meter case. If meter pointer pins sharply against right hand stop, tubes V1 and/or V2 are microphonic.

TABLE 4-2. TROUBLE SHOOTING CHART (CONT'D)

Symptom	Possible Cause and/or Remedy
Microphonics (Cont'd.)	<p>If instrument seems to be equally microphonic on the 0.3 volt range with 0.3 volt input, change V2. If instrument is less microphonic on the 0.3 volt range, replace V1.</p> <p>Poor electrical contact in range switch. Clean and inspect switch contacts. Use a cleaning solvent that will not leave a deposit. <u>Do not disturb any wires.</u></p> <p>Check all solder connections. Loose or imperfect joints will appear as microphonics.</p> <p>V3, V4, and V5 may also cause microphonics.</p>
Response at 10 cps is low or high.	One or more weak tubes (try V3 and V4 first), defective coupling capacitor (C18, C19, etc.), or defective cathode by-pass capacitor (C20, etc.).
Response at 4 mc low.	Weak tubes (V1 through V5).
Motorboating.	<p>Motorboating may be caused by low voltage from the regulated power supply, or from low ac line conditions.</p> <p>Weak V2, V3, V4, V5 (see paragraph 4-10 to locate trouble).</p> <p>Trouble in power supply (see paragraph 4-9).</p>
High plate or screen voltage for V2, V3, V4, and/or V5.	<p>Weak or defective tube. Refer to paragraph 4-10.</p> <p>Open cathode resistor.</p>
Low plate or screen voltage for V2, V3, V4, and/or V5.	<p>Defective grid coupling, cathode, or screen by-pass capacitor. Refer to paragraph 4-10.</p> <p>Defective tube.</p>
Voltmeter reads high or low on two voltage ranges that are multiples of 1000 apart.	Defective range switch component(s). Correct by replacing entire range switch assembly.

4-9 POWER SUPPLY TROUBLE LOCALIZATION

If trouble is localized to the power-supply section, the following checks will be helpful in trouble shooting.

- 1) Set line voltage to exactly 115 volts.
- 2) The dc voltage at plate pin 9 of 12B4A series regulator tube V7 or at cathode pin 8 of 6AX5 rectifier tube V6 should be between 400 and 420 volts.

Low voltage at this point may be due to rectifier tube V6, power transformer T1, or input capacitor C30 being defective.

To check V6, connect a dc voltmeter between pin 8 of V6 and chassis. Reduce line voltage from 115 to 103 volts. The dc voltmeter reading should drop immediately when the ac line voltage is reduced and then remain steady. If the dc voltage continues to drop at a slow rate, rectifier V6 is probably weak and should be replaced.

- 3) The dc voltage between pin 1 of tube V7 and chassis should be 250 volts, ± 5 volts.

If the regulated voltage is not within this range, replacement of V6, V7, V8 and/or V9 may be necessary. If changing these tubes does not correct the dc voltage level, resistors R62 and/or R64 may have changed value and should be replaced.

- 4) Check power supply regulation and dc heater voltage as outlined in paragraphs 4-7B and 4-7C.

4-10 AMPLIFIER TROUBLE LOCALIZATION

To localize trouble by dc voltage analysis, the following checks will be helpful.

- 1) With a line voltage of exactly 115 volts, check the dc plate (pin 5) and screen (pin 6) voltages for V1, V2, V3, V4, and V5.

Plate and screen of V1 are tied together and should have a dc voltage of +165 volts, ± 5 volts.

Tubes V2, V3, and V4 should have a plate voltage of at least +90 volts but no higher than +135 volts.

Plate voltage for V5 should fall between +125 and +145 volts.

Screen voltages for V2, V3, V4 and V5 should be +135 volts, ± 10 volts.

- 2) Reduce line voltage to 103 volts. Again measure V2 through V5 dc plate and screen voltages.

If a tube is weak, plate and screen voltages will drift to a higher value after the initial slight change following the reduction in line voltage. This effect will be more noticeable at the plate of each tube.

- 3) Reset line voltage to 115 volts. Check that voltage from pin 3 of V3 or V4 to chassis measures 12.6 volts; readjust R66, if necessary. Measure dc voltage at grid pin 1 of V2, V3, V4, and V5. A reading of zero volts will normally be obtained for V2, V3, and V4. The grid of V5 will be approximately +0.6 volt with respect to the chassis. A high-impedance vacuum tube voltmeter such as the Φ Model 410B must be used for this measurement.

Leaking coupling capacitors from a previous stage will cause a more positive dc grid-voltage for V2, V3, V4, or V5. Replace any coupling capacitors in doubtful condition.

Occasionally a coupling capacitor will be found that is slightly leaky only when the instrument is operated in its case. When the instrument is operated with its case off, components are permitted to cool off to below normal operating temperatures.

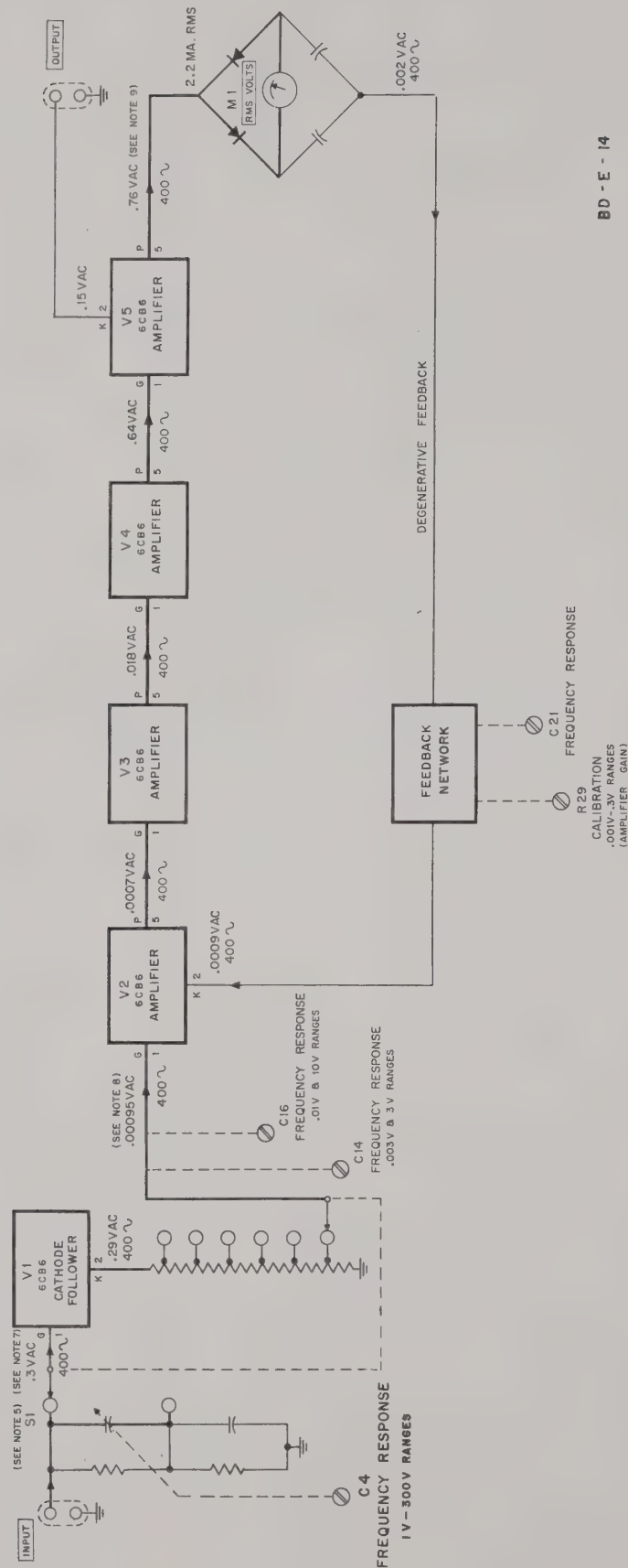
- 4) A cathode voltage of approximately +1.4 volts is normal for V2, +1.1 volts for V3 and V4, and +1.6 volts for V5.

An open cathode resistor will result in a relatively large increase in these voltages. A weak tube or a defective cathode bypass capacitor can result in low cathode voltage.

- 5) A cathode voltage of approximately +58 volts and grid voltage of +56 volts is normal for the grid of V1. Measure the grid voltage at the junction of R1 (110K) and R7 (220K) at terminal of capacitor C1 behind the pilot lamp socket (see Figure 4-1).

The actual values will vary slightly, but the cathode voltage will always be about 2 volts positive compared to the grid.

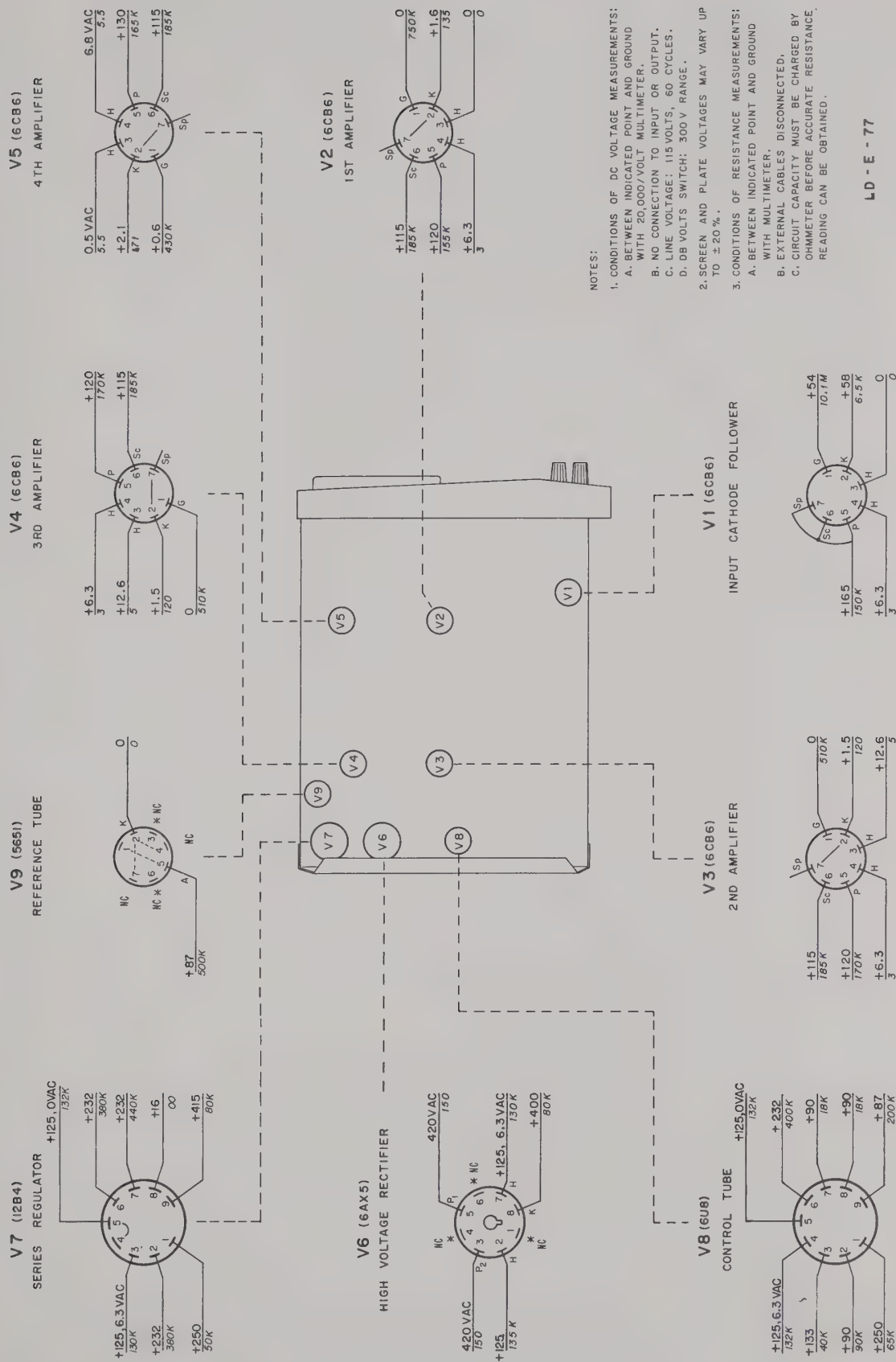
With a weak V1 the bias will be less than 1 volt which will show up as instability when the range switch is rotated.



NOTES:

1. Heavy line indicates main circuit.
2. Light line indicates auxiliary circuits or controls.
3. Variable controls are indicated by circle and dotted line dropped from point in circuit where connected. Line thru circle indicates screwdriver control.
4. Letters and numbers outside tube blocks indicate tube element and socket pin.
5. S1 = DB VOLTS (range) switch.
6. Conditions of voltage measurement
 - A. Input signal: .3V rms, 400 Ω
 - B. DB VOLTS switch: .3V range
 - C. Between indicated point and ground.
7. Voltage will vary with level of input signal and position of S1; should not exceed .3V at 400 Ω .
8. Signal measurements in first stage not practical due to extremely low signal level and large degeneration applied to V2.
9. CAUTION - When checking tube V5, avoid shorting crystal diodes CR1 and CR2 to ground. With power turned on, the diodes will burn out if their terminals are shorted to ground.

Figure 4-3. Model 400D/H/L Servicing Block Diagram



NOTES:

1. CONDITIONS OF DC VOLTAGE MEASUREMENTS:
A. BETWEEN INDICATED POINT AND GROUND WITH 20,000/VOLT MULTIMETER.
B. NO CONNECTION TO INPUT OR OUTPUT.
C. LINE VOLTAGE: 115 VOLTS, 60 CYCLES.
D. DB VOLTS SWITCH: 300 V RANGE.
2. SCREEN AND PLATE VOLTAGES MAY VARY UP TO $\pm 20\%$.
3. CONDITIONS OF RESISTANCE MEASUREMENTS:
A. BETWEEN INDICATED POINT AND GROUND WITH MULTIMETER.
B. EXTERNAL CABLES DISCONNECTED.
C. CIRCUIT CAPACITY MUST BE CHARGED BY OHMMETER BEFORE ACCURATE RESISTANCE READING CAN BE OBTAINED.

LD - E - 77

Figure 4-4. Model 400D/H/L Voltage and Resistance Diagram

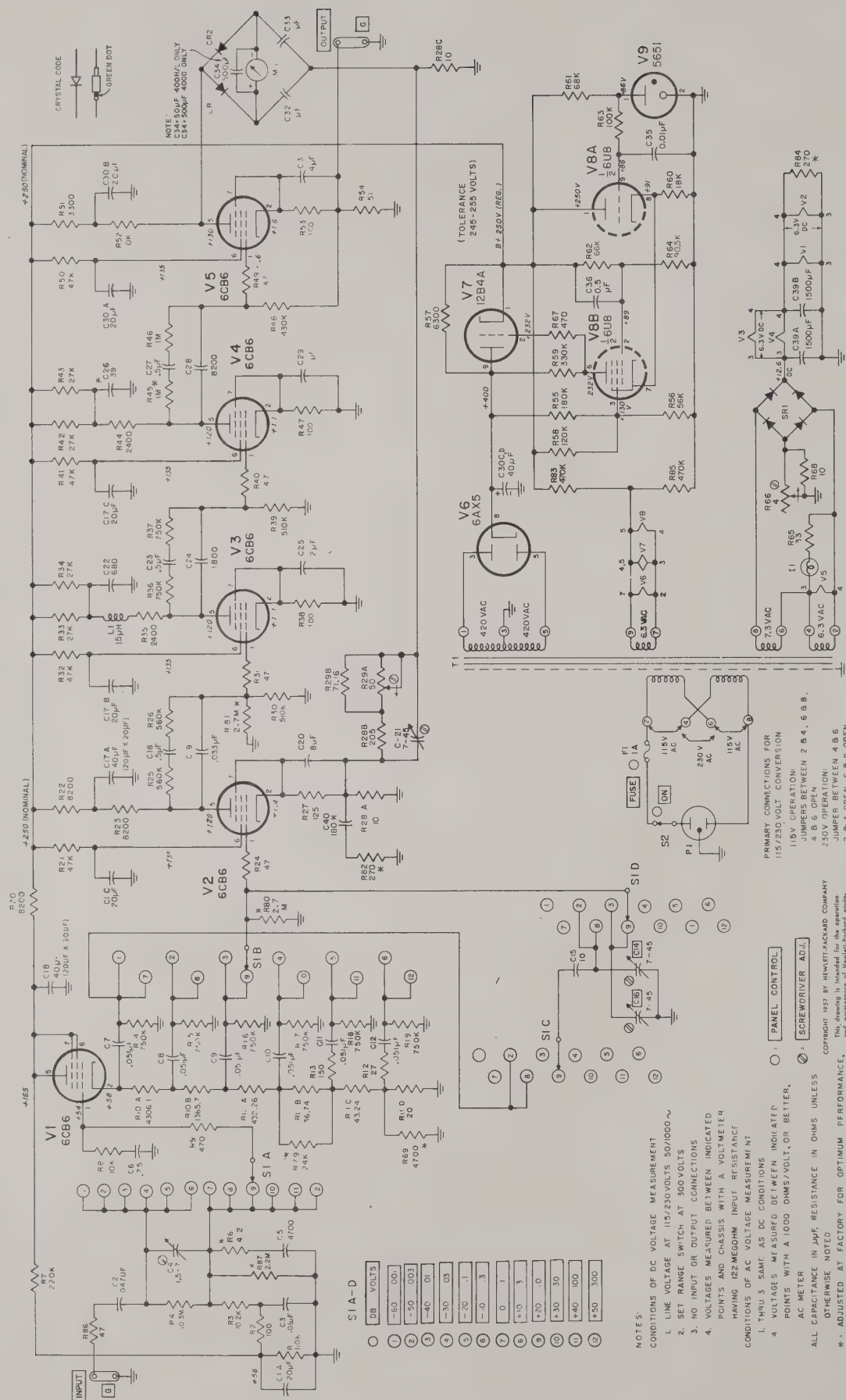


Figure 4-5. Model 400D/H/L Vacuum Tube Voltmeter Schematic Diagram


SECTION V

TABLE OF REPLACEABLE PARTS

NOTE

Readily available standard-components have been used in this instrument, whenever possible. However, special components may be obtained from your local Hewlett-Packard representative or from the factory.

When ordering parts always include:

1.  Stock Number.
2. Complete description of part including circuit reference.
3. Model number and serial number of instrument.
4. If part is not listed give complete description, function, and location of part.

If there are any corrections for the Table of Replaceable Parts they will be listed on an Instruction Manual Change sheet at the front of this manual.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	STOCK NO.	#			
C1	Capacitor: fixed, electrolytic, 4 sections, 20 μ f/sect., 450 vdcw CC*	18-42HP	3			
C2	Capacitor: fixed, paper, .047 μ f, \pm 10%, 600 vdcw CC*	16-15	1			
C3	Capacitor: fixed, ceramic, .01 μ f, tol. -0% +100%, 1000 vdcw CC*	15-43	2			
C4	Capacitor: variable, ceramic, 1.5 to 7 μ f, 500 vdcw L*	13-7	1			
C5	Capacitor: fixed, silver mica, .0047 μ f, \pm 5%, 500 vdcw V*	15-81	1			
C6	Capacitor: fixed, .75 μ f (air gap between R8 lug and ground lug of tie point)					
C7 thru C12	Capacitor: fixed, paper, .051 μ f, \pm 5%, 600 vdcw CC*	16-53	6			
C13	This circuit reference not assigned					
C14	Capacitor: variable, ceramic, 7 to 45 μ f, 500 vdcw L*	13-1	3			
C15	Capacitor: fixed, ceramic, 10 μ f, \pm .5 μ f, 500 vdcw K*	15-30	1			
C16	Same as C14					
C17	Same as C1					
C18	Capacitor: fixed, paper, 0.5 μ f, \pm 10%, 400 vdcw J*	16-58	4			
C19	Capacitor: fixed, paper, .033 μ f, \pm 10%, 600 vdcw CC*	16-13	1			
C20	Capacitor: fixed, electrolytic, 8 μ f, -15% +20%, 30 vdcw AH*	18-17	1			
C21	Same as C14					
C22	Capacitor: fixed, mica, 680 μ f, \pm 10%, 500 vdcw Z*	14-21	1			

* See "List of Manufacturers Code Letters For Replaceable Parts Table".

Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	Ⓢ STOCK NO.	#			
C23	Same as C18					
C24	Capacitor: fixed, mica, 1800 μ f, $\pm 10\%$, 500 vdcw Z*	14-47	1			
C25	Capacitor: fixed, paper, 2.0 μ f, $-15\% +25\%$, 200 vdcw RR*	16-67	1			
C26	Capacitor: fixed, mica, 39 μ f, $\pm 5\%$, 300 vdcw Electrical value adjusted at factory V*	14-70	1			
C27	Same as C18					
C28	Capacitor: fixed, mica, 8200 μ f, $\pm 10\%$, 500 vdcw J*	15-98	1			
C29	Capacitor: fixed, paper, 1.0 μ f, $-15\% +25\%$, 200 vdcw RR*	16-66	1			
R30	Same as C1					
C31	Capacitor: fixed, electrolytic, 4 μ f, $-15\% +20\%$, 60 vdcw AH*	18-15	1			
C32, 33	Capacitor: fixed, paper, 1 μ f, $\pm 10\%$, 400 vdcw J*	16-74	2			
C34	Capacitor: fixed, electrolytic, 500 μ f, 15 vdcw (400D ONLY) X*	18-5	1			
	Capacitor: fixed, electrolytic, 50 μ f, $-10\% +20\%$ (400H/L ONLY) A*	18-50	1			
C35	Same as C3					
C36	Same as C18					
C37, 38	These circuit references not assigned					
C39	Capacitor: fixed, electrolytic, 2 sections, 1500 μ f/sect., 15 vdcw CC*	18-48HP	1			
C40	Capacitor: fixed, mica, 180 μ f, $\pm 10\%$, 500 vdcw Z*	14-51	1			

* See "List of Manufacturers Code Letters For Replaceable Parts Table".

Total quantity used in the instrument.


TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	STOCK NO.	#			
CR1, 2	Rectifier, silicon diode special ϕ design HP*	G-29B-5	2			
F1	Fuse, cartridge: 1 amp, "slo-blo" (115V operation) E*	211-18	1			
	or: Fuse, cartridge: 0.5 amp, "slo-blo" (230V operation) E*	211-20				
I1	Lamp, incandescent: 6-8V, .15 amp, #47 N*	211-47	1			
L1	Coil, R.F.: 15 μ h CG*	48-64	1			
M1	Meter: Model 400D HP* Model 400D (with db scale above voltage scales) HP* Model 400H HP*	112-6 112-76 112-66	1 1 1			
	Model 400L HP* Model 400L (with voltage scales above db scale) HP*	112-104 112-85	1			
P1	Cable, power Elec. Cords Co.	812-56	1			
R1	Resistor: fixed, composition, 110,000 ohms, $\pm 5\%$, 1 W B*	24-110K-5	1			
R2	Resistor: fixed, composition, 100 ohms, $\pm 10\%$, 1/2 W B*	23-100	1			
R3, 4	Resistor: fixed, matched, R3 - 10.31K ohms R4 - 10.3M ohms HP*	400D-67	2			
R5	This circuit reference not assigned					

* See "List of Manufacturers Code Letters For Replaceable Parts Table".

Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	 STOCK NO.	#			
R6	Resistor: fixed, composition, 4.2 ohms, $\pm 10\%$, 1/2 W (May consist of two 10 ohms and one 27 ohms, $\pm 10\%$, 1/2 W, all connected in parallel.) Electrical value adjusted at factory					
R7	Resistor: fixed, composition, 220,000 ohms, $\pm 10\%$, 1 W B*	24-220K	1			
R8	Resistor: fixed, composition, 10,000 ohms, $\pm 10\%$, 1/2 W B*	23-10K	1			
R9	Resistor: fixed, composition, 470 ohms, $\pm 10\%$, 1/2 W B*	23-470	2			
R10, 11	Resistor: fixed, wirewound, (400D ONLY) HP*	400D-71	1			
	Resistor: fixed, wirewound, (400H/L ONLY) HP*	400H-71	1			
R12	Resistor: fixed, composition, 27 ohms, $\pm 10\%$, 1/2 W B*	23-27	1			
R13	Resistor: fixed, composition, 150 ohms, $\pm 10\%$, 1/2 W B*	23-150	1			
R14 thru R19	Resistor: fixed, composition, 750,000 ohms, $\pm 5\%$, 1/2 W B*	23-750K-5	8			
R20	Resistor: fixed, composition, 8200 ohms, $\pm 10\%$, 2 W B*	25-8200	2			
R21	Resistor: fixed, composition, 47,000 ohms, $\pm 10\%$, 1 W B*	24-47K	4			
R22	Same as R20					
R23	Resistor: fixed, metal film, 8200 ohms, $\pm 5\%$, 1 W AB*	331-8200	1			
R24	Resistor: fixed, composition, 47 ohms, $\pm 10\%$, 1/2 W B*	23-47	5			
R25, 26	Resistor: fixed, composition, 560,000 ohms, $\pm 10\%$, 1/2 W B*	23-560K	2			
R27	Resistor: fixed, wirewound, 125 ohms, $\pm 10\%$, 2 W AC*	26-58	1			

* See "List of Manufacturers Code Letters For Replaceable Parts Table".

Total quantity used in the instrument.


TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	STOCK NO.	#			
R28 AC	Resistor: fixed, wirewound HP*	400D-26B	1			
R28 B	Resistor: fixed, wirewound HP*	400D-26C	1			
R29 A	Resistor: variable, composition, 50 ohms, $\pm 10\%$, 2 W B*	210-186	1			
R29 B	Resistor: fixed, deposited carbon, 71.16 ohms, $\pm 1\%$, 1/2 W NN*	33-71.16	1			
R30	Resistor: fixed, composition, 510,000 ohms, $\pm 5\%$, 1/2 W B*	23-510K-5	2			
R31	Same as R24					
R32	Same as R21					
R33, 34	Resistor: fixed, composition, 27,000 ohms, $\pm 10\%$, 2 W B*	25-27K	4			
R35	Resistor: fixed, composition, 2400 ohms, $\pm 5\%$, 1 W B*	24-2400-5	2			
R36, 37	Same as R14					
R38	Resistor: fixed, composition, 100 ohms, $\pm 10\%$, 1 W B*	24-100	3			
R39	Same as R30					
R40	Same as R24					
R41	Same as R21					
R42, 43	Same as R33					
R44	Same as R35					
R45, 46	Resistor: fixed, composition, 1 megohm, $\pm 10\%$, 1/2 W B*	23-1M	2			
R47	Same as R38					
R48	Resistor: fixed, composition, 430,000 ohms, $\pm 5\%$, 1/2 W B*	23-430K-5	1			

* See "List of Manufacturers Code Letters For Replaceable Parts Table".

Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	 STOCK NO.	#			
R49	Same as R24					
R50	Same as R21					
R51	Resistor: fixed, composition, 3300 ohms, $\pm 10\%$, 1 W	B* 24-3300	1			
R52	Resistor: fixed, composition, 10,000 ohms, $\pm 10\%$, 2 W	B* 25-10K	1			
R53	Same as R38					
R54	Resistor: fixed, composition, 51 ohms, $\pm 5\%$, 1 W	B* 24-51-5	1			
R55	Resistor: fixed, composition, 180,000 ohms, $\pm 10\%$, 2 W	B* 25-180K	1			
R56	Resistor: fixed, composition, 56,000 ohms, $\pm 10\%$, 1 W	B* 24-56K	1			
R57	Resistor: fixed, wirewound, 6300 ohms, $\pm 10\%$, 10 W	S* 26-61	1			
R58	Resistor: fixed, composition, 120,000 ohms, $\pm 10\%$, 1 W	B* 24-120K	1			
R59	Resistor: fixed, composition, 330,000 ohms, $\pm 10\%$, 1 W	B* 24-330K	1			
R60	Resistor: fixed, composition, 18,000 ohms, $\pm 10\%$, 1 W	B* 24-18K	1			
R61	Resistor: fixed, composition, 68,000 ohms, $\pm 10\%$, 1 W	B* 24-68K	1			
R62	Resistor: fixed, deposited carbon, 166,000 ohms, $\pm 1\%$, 1 W	NN* 31-166K	1			
R63	Resistor: fixed, composition, 100,000 ohms, $\pm 10\%$, 1/2 W	B* 23-100K	1			
R64	Resistor: fixed, deposited carbon, 90,500 ohms, $\pm 1\%$, 1 W	NN* 31-90.5K	1			
R65	Resistor: fixed, composition, 33 ohms, $\pm 10\%$, 1 W	B* 24-33	1			

* See "List of Manufacturers Code Letters For Replaceable Parts Table".

Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	STOCK NO.	#			
R66	Resistor: variable, wirewound, 4 ohms, $\pm 20\%$, 1 W AT*	210-114	1			
R67	Same as R9					
R68	Resistor: fixed, composition, 10 ohms, $\pm 10\%$, 1 W B*	24-10	1			
R69	Resistor: fixed, composition, 4700 ohms, $\pm 10\%$, 1/2 W Electrical value adjusted at factory B*	23-4700	1			
R70 thru R78	These circuit references not assigned					
R79	Resistor: fixed, composition, 24,000 ohms, $\pm 5\%$, 1/2 W Electrical value adjusted at factory - may not be present B*	23-24K-5	1			
R80, 81	Resistor: fixed, composition, 2.7 megohms, $\pm 10\%$, 1/2 W Electrical value adjusted at factory - may not be present B*	23-2.7M	2			
R82	Resistor: fixed, composition, 270 ohms, $\pm 10\%$, 1/2 W Electrical value adjusted at factory - may not be present B*	23-270	1			
R83	Resistor: fixed, composition, 470,000 ohms, $\pm 10\%$, 1/2 W B*	23-470K	2			
R84	Resistor: fixed, composition, 270 ohms, $\pm 10\%$, 1 W Electrical value adjusted at factory - may not be present B*	24-270	1			
R85	Same as R83					
R86	Same as R24					
R87	Resistor: fixed, composition, 2.2 megohms, $\pm 10\%$, 1/2 W Electrical value adjusted at factory - may not be present B*	23-2.2M	1			

* See "List of Manufacturers Code Letters For Replaceable Parts Table".

Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	Ⓢ STOCK NO.	#			
S1	Range Switch Assembly (400D ONLY) HP*	400D-19W	1			
	Range Switch Assembly (400H/L ONLY) HP*	400H-19W	1			
S2	Switch, Toggle: SPST D*	310-11	1			
SR1	Rectifier, metallic BV*	212-101	1			
T1	Transformer, power HP*	910-113	1			
V1, 2	Tube, electron: 6CB6 ZZ* Tubes selected for best performance will be supplied by Ⓢ (if ordered by Ⓢ stock number) but tubes meeting RETMA standards will normally result in the instrument oper- ating within specifications.	G-73W	2			
V3, 4, 5	Tube, electron: 6CB6 ZZ*	212-6CB6	3			
V6	Tube, electron: 6AX5-GT ZZ*	212-6AX5- GT	1			
V7	Tube, electron: 12B4A ZZ*	212-12B4A	1			
V8	Tube, electron: 6U8 ZZ*	212-6U8	1			
V9	Tube, electron: 5651 ZZ*	212-5651	1			
	<u>MISCELLANEOUS</u>					
	Binding Post Assembly: black HP*	AC-10C	2			
	Binding Post Assembly: red HP*	AC-10D	2			
	Holder, fuse T*	140-16	1			
	Handle, cabinet. HP*	144-5	1			
	Insulator, binding post: single HP*	AC-54D	2			
	Insulator, binding post: double HP*	AC-54A	2			
	Knob: range switch HP*	G-74N	1			

* See "List of Manufacturers Code Letters For Replaceable Parts Table".

Total quantity used in the instrument.

LIST OF CODE LETTERS USED IN TABLE OF REPLACEABLE PARTS TO DESIGNATE THE MANUFACTURERS

CODE LETTER	MANUFACTURER	ADDRESS	CODE LETTER	MANUFACTURER	ADDRESS
A	Aerovox Corp.	New Bedford, Mass.	AK	Hammerlund Mfg. Co., Inc.	New York 1, N. Y.
B	Allen-Bradley Co.	Milwaukee 4, Wis.	AL	Industrial Condenser Corp.	Chicago 18, Ill.
C	Amperite Co.	New York, N. Y.	AM	Insuline Corp. of America	Manchester, N. H.
D	Arrow, Hart & Hegeman	Hartford, Conn.	AN	Jennings Radio Mfg. Corp.	San Jose, Calif.
E	Bussman Manufacturing Co.	St. Louis, Mo.	AO	E. F. Johnson Co.	Waseca, Minn.
F	Carborundum Co.	Niagara Falls, N. Y.	AP	Lenz Electric Mfg. Co.	Chicago 47, Ill.
G	Centralab	Milwaukee 1, Wis.	AQ	Micro-Switch	Freeport, Ill.
H	Cinch-Jones Mfg. Co.	Chicago 24, Ill.	AR	Mechanical Industries Prod. Co.	Akron 8, Ohio
HP	Hewlett-Packard Co.	Palo Alto, Calif.	AS	Model Eng. & Mfg., Inc.	Huntington, Ind.
I	Clarostat Mfg. Co.	Dover, N. H.	AT	The Muter Co.	Chicago 5, Ill.
J	Cornell Dubilier Elec. Co.	South Plainfield, N. J.	AU	Ohmite Mfg. Co.	Skokie, Ill.
K	Hi-Q Division of Aerovox	Olean, N. Y.	AV	Resistance Products Co.	Harrisburg, Pa.
L	Erie Resistor Corp.	Erie 6, Pa.	AW	Radio Condenser Co.	Camden 3, N. J.
M	Fed. Telephone & Radio Corp.	Clifton, N. J.	AX	Shallcross Manufacturing Co.	Collingdale, Pa.
N	General Electric Co.	Schenectady 5, N. Y.	AY	Solar Manufacturing Co.	Los Angeles 58, Calif.
O	General Electric Supply Corp.	San Francisco, Calif.	AZ	Sealectro Corp.	New Rochelle, N. Y.
P	Girard-Hopkins	Oakland, Calif.	BA	Spencer Thermostat	Attleboro, Mass.
Q	Industrial Products Co.	Danbury, Conn.	BC	Stevens Manufacturing Co.	Mansfield, Ohio
R	International Resistance Co.	Philadelphia 8, Pa.	BD	Torrington Manufacturing Co.	Van Nuys, Calif.
S	Lectrohm Inc.	Chicago 20, Ill.	BE	Vector Electronic Co.	Los Angeles 65, Calif.
T	Littlefuse Inc.	Des Plaines, Ill.	BF	Weston Electrical Inst. Corp.	Newark 5, N. J.
U	Maguire Industries Inc.	Greenwich, Conn.	BG	Advance Electric & Relay Co.	Burbank, Calif.
V	Micamold Radio Corp.	Brooklyn 37, N. Y.	BH	E. I. DuPont	San Francisco, Calif.
W	Oak Manufacturing Co.	Chicago 10, Ill.	BI	Electronics Tube Corp.	Philadelphia 18, Pa.
X	P. R. Mallory Co., Inc.	Indianapolis, Ind.	BJ	Aircraft Radio Corp.	Boonton, N. J.
Y	Radio Corp. of America	Harrison, N. J.	BK	Allied Control Co., Inc.	New York 21, N. Y.
Z	Sangamo Electric Co.	Marion, Ill.	BL	Augat Brothers, Inc.	Attleboro, Mass.
AA	Sarkes Tarzian	Bloomington, Ind.	BM	Carter Radio Division	Chicago, Ill.
BB	Signal Indicator Co.	Brooklyn 37, N. Y.	BN	CBS Hytron Radio & Electric	Danvers, Mass.
CC	Sprague Electric Co.	North Adams, Mass.	BO	Chicago Telephone Supply	Elkhart, Ind.
DD	Stackpole Carbon Co.	St. Marys, Pa.	BP	Henry L. Crowley Co., Inc.	West Orange, N. J.
EE	Sylvania Electric Products Co.	Warren, Pa.	BQ	Curtiss-Wright Corp.	Carlstadt, N. J.
FF	Western Electric Co.	New York 5, N. Y.	BR	Allen B. DuMont Labs	Clifton, N. J.
GG	Wilkor Products, Inc.	Cleveland, Ohio	BS	Excel Transformer Co.	Oakland, Calif.
HH	Amphenol	Chicago 50, Ill.	BT	General Radio Co.	Cambridge 39, Mass.
II	Dial Light Co. of America	Brooklyn 37, N. Y.	BU	Hughes Aircraft Co.	Culver City, Calif.
JJ	Leecraft Manufacturing Co.	New York, N. Y.	BV	International Rectifier Corp.	El Segundo, Calif.
KK	Switchcraft, Inc.	Chicago 22, Ill.	BW	James Knights Co.	Sandwich, Ill.
LL	Gremar Manufacturing Co.	Wakefield, Mass.	BX	Mueller Electric Co.	Cleveland, Ohio
MM	Carad Corp.	Redwood City, Calif.	BY	Precision Thermometer & Inst. Co.	Philadelphia 30, Pa.
NN	Electra Manufacturing Co.	Kansas City, Mo.	BZ	Radio Essentials Inc.	Mt. Vernon, N. Y.
OO	Acro Manufacturing Co.	Columbus 16, Ohio	CA	Raytheon Manufacturing Co.	Newton, Mass.
PP	Alliance Manufacturing Co.	Alliance, Ohio	CB	Tung-Sol Lamp Works, Inc.	Newark 4, N. J.
QQ	Arco Electronics, Inc.	New York 13, N. Y.	CD	Varian Associates	Palo Alto, Calif.
RR	Astron Corp.	East Newark, N. J.	CE	Victory Engineering Corp.	Union, N. J.
SS	Axel Brothers Inc.	Long Island City, N. Y.	CF	Weckesser Co.	Chicago 30, Ill.
TT	Belden Manufacturing Co.	Chicago 44, Ill.	CG	Wilco Corporation	Indianapolis, Ind.
UU	Bird Electronics Corp.	Cleveland 14, Ohio	CH	Winchester Electronics, Inc.	Santa Monica, Calif.
VV	Barber Colman Co.	Rockford, Ill.	CI	Malco Tool & Die	Los Angeles 42, Calif.
WW	Bud Radio Inc.	Cleveland 3, Ohio	CJ	Oxford Electric Corp.	Chicago 15, Ill.
XX	Allen D. Cardwell Mfg. Co.	Plainville, Conn.	CK	Camloc-Fastener Corp.	Paramus, N. J.
YY	Cinema Engineering Co.	Burbank, Calif.	CL	George K. Garrett	Philadelphia 34, Pa.
ZZ	Any brand tube meeting RETMA standards.		CM	Union Switch & Signal	Swissvale, Pa.
AB	Corning Glass Works	Corning, N. Y.	CN	Radio Receptor	New York 11, N. Y.
AC	Dale Products, Inc.	Columbus, Neb.	CO	Automatic & Precision Mfg. Co.	Yonkers, N. Y.
AD	The Drake Mfg. Co.	Chicago 22, Ill.	CP	Bassick Co.	Bridgeport 2, Conn.
AE	Elco Corp.	Philadelphia 24, Pa.	CQ	Birnbach Radio Co.	New York 13, N. Y.
AF	Hugh H. Eby Co.	Philadelphia 44, Pa.	CR	Fischer Specialties	Cincinnati 6, Ohio
AG	Thomas A. Edison, Inc.	West Orange, N. J.	CS	Telefunken (c/o MVM, Inc.)	New York, N. Y.
AH	Fansteel Metallurgical Corp.	North Chicago, Ill.	CT	Potter-Brumfield Co.	Princeton, Ind.
AI	General Ceramics & Steatite Corp.	Keasbey, N. J.	CU	Cannon Electric Co.	Los Angeles, Calif.
AJ	The Gudeman Co.	Sunnyvale, Calif.	CV	Dynac, Inc.	Palo Alto, Calif.
			CW	Good-All Electric Mfg. Co.	Ogallala, Nebr.

CLAIM FOR DAMAGE IN SHIPMENT

The instrument should be tested as soon as it is received. If it fails to operate properly, or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent, and this report should be forwarded to us. We will then advise you of the disposition to be made of the equipment and arrange for repair or replacement. Include model number and serial number when referring to this instrument for any reason.

WARRANTY

Hewlett-Packard Company warrants each instrument manufactured by them to be free from defects in material and workmanship. Our liability under this warranty is limited to servicing or adjusting any instrument returned to the factory for that purpose and to replace any defective parts thereof. Klystron tubes as well as other electron tubes, fuses and batteries are specifically excluded from any liability. This warranty is effective for one year after delivery to the original purchaser when the instrument is returned, transportation charges prepaid by the original purchaser, and when upon our examination it is disclosed to our satisfaction to be defective. If the fault has been caused by misuse or abnormal conditions of operation, repairs will be billed at cost. In this case, an estimate will be submitted before the work is started.

If any fault develops, the following steps should be taken:

1. Notify us, giving full details of the difficulty, and include the model number and serial number. On receipt of this information, we will give you service data or shipping instructions.
2. On receipt of shipping instructions, forward the instrument prepaid, to the factory or to the authorized repair station indicated on the instructions. If requested, an estimate of the charges will be made before the work begins provided the instrument is not covered by the warranty.

SHIPPING

All shipments of Hewlett-Packard instruments should be made via Truck or Railway Express. The instruments should be packed in a strong exterior container and surrounded by two or three inches of excelsior or similar shock-absorbing material.

DO NOT HESITATE TO CALL ON US

HEWLETT-PACKARD COMPANY

Laboratory Instruments / *for Speed and Accuracy*

275 PAGE MILL ROAD

CABLE



PALO ALTO, CALIF. U.S.A.

"HEWPACK"

